DESIGN-TO-COST: CONCEPT AND APPLICATION

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THESIS

DESIGN-TO-COST: CONCEPT AND APPLICATION

by

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December 1974

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Design-to-Cost has been instituted as one of several reforms to Department of Defense procurement practices. This thesis presents historical needs for such reforms. Design-to-Cost is described and placed in context with other policy revisions. Impacts of recent changes and resultant controversies are explored. Sample cases display the actual implementation of Design-to-Cost. Problem areas are enumerated and remedial

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAH	advanced attack helicopter
ACF	air combat fighter
ALCM	air launched cruise missile
ALRAAM	advanced long range air-to-air missile
ASD	Aeronautical Systems Division
ASPR	Armed Services Procurement Regulations
CAIG	Cost Analysis Improvement Group
CAS	close air support
CER	cost estimating relationship
CFP	Concept Formulation Package
CPAF	cost plus award fee
CPI	Consumer Price Index
CPIF	cost plus incentive fee
CPP	concept prototype phase
C/SCSC	Cost/Schedule Control Systems Criteria
DCP	Development Concept Paper
DOD	Department of Defense
DSARC	Defense Systems Acquisition Review Council
DTC	design-to-cost
ECO	engineering change order
ECP	engineering change proposal
FY	fiscal year
GAO	Government Accounting Office
GFE	government furnished equipment

HARM	high speed anti-radiation missile
ILS	integrated logistic support
IWDS	improved weapons delivery system
LCC	life cycle cost
LWF	lightweight fighter
MIS	management information system
NWC	Naval Weapons Center
O&S	operations and support
OSD	Office of the Secretary of Defense
PM	project manager
PPB	Planning Programming Budgeting
PPO	Prototype Programs Office
R&D	research and development
RDT&E	research, development, test and evaluation
RFP	request for proposal
SCAD	subsonic cruise armed decoy
SECDEF	Secretary of Defense
SPO	Systems Program Office
SYSCOM	Systems Command
UPC	unit production cost
UTTAS	utility tactical transport aircraft
WBS	work breakdown structure

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I. INTRODUCTION

The Department of Defense (DOD) has undergone sweeping changes during recent years with respect to its procurement practices. Many new policies have been instituted, either as temporary fixes, or as possible long range solutions to diverse procurement problems. As with most sudden organizational changes, the reactions to these changes have been mixed. This thesis addresses the implementation of Design-to-Cost (DTC) from the points of view of policy and applications.

A. PURPOSE OF THE PAPER

Since the middle 1960's DOD has experienced gigantic increases in weapon system costs. This has been accompanied by increasing criticism, charges of mismanagement, and, in some cases, accusations of outright dishonesty and fraud on the parts of both government employees and contractors. Reactions by the press, public, and Congress have resulted in closer scrutiny than ever before of DOD policies and actions. The defense budget, once by far the largest component of federal spending, has become a favorite target for cost cutters of various motivations. As a result, DOD funding has remained relatively fixed in purchasing power while overall governmental spending sets new records each year. As a result, the growing costs of developing systems are rapidly outstripping DOD's ability to afford them. Prospects for softening

of these budgetary constraints in the foreseeable future are dim (Ref. 1).

The manner in which DTC was imposed by the Secretary of Defense (SECDEF) in the early 1970's gave little direct guidance concerning its application. Having been provided with only a general statement of policy, lower level managers were left in a position of having to solve many of the practical problems of its implementation. Such an approach, while being very broad and flexible, has also led to a large amount of uncertainty and confusion. The volumes of material written since have only partially alleviated the problem.

Life cycle cost (LCC), the overall cost of development, acquisition, ownership, and disposal of a system, has been imposed as a primary design parameter. In practice, however, this has been true only in rare instances, not because of disinterest, but rather because few people, if any, know how to do it. Weapon system life cycle costs have little in the way of historical material from which to draw. The data that does exist is largely unavailable or grossly distorted by inconsistent cost definitions and accounting practices. In an effort to overcome these difficulties, parametric cost estimating relationships (CER) have been developed. This is a new concept, which uses available empirical historical cost data to predict new weapon system costs. Being new, the applicability and reliability of CER's is not yet fully demonstrated.

Rather than designing to minimize life cycle costs, minimum unit production costs (UPC) have become the primary

cost considerations. This is more or less by default, due to state of the art limitations for defining LCC. Even this UPC is subject to differing definitions. Studies have shown a lack of a standardized approach to any of these problems.

Finally, there is a serious question as to how or even if Design-to-Cost should be applied to procurement projects already in development.

The intent of this study is to offer some recommendations toward the solution of the many problems confronting the implementation of Design-to-Cost, and to suggest areas in which further study is required. In order to accomplish this, a comprehensive literature review was performed. This was followed by field trips to the Naval Weapons Center (NWC) China Lake, California where the concept is being applied to various naval weapon system procurements. The authors interviewed the management personnel responsible for contract development and administration at a variety of project offices to obtain first hand information concerning the current problems being faced by middle management. In addition to this, telephone interviews were conducted with personnel associated with other Navy, Army, and Air Force projects.

The programs selected for review are all aerospace projects; however, they range in size from a small subsystem component procurement to a major weapon system acquisition. The stage of development of the selected programs also varies, from the early stages of conceptual planning in one case, to another for which a contract was awarded for initial production.

B. DEFINITIONS OF DESIGN-TO-COST

The confusion and controversy concerning DTC begins with basic aims and definitions. As will be shown, the major policy setting levels within DOD have not agreed upon some important points.

The Secretary of Defense in imposing DTC upon the services in DOD Directive 5000.1 (Ref. 2) stated:

> "Cost parameters shall be established which consider the cost of acquisition and ownership; discrete cost elements (e.g., unit production cost, operating and support cost) shall be translated into 'design to' requirements. System development shall be continuously evaluated against these requirements with the same rigor as that applied to technical requirements. Practical tradeoffs shall be made between system capability, cost, and schedule."

Thus, one sees that basic DTC philosophy is built around LCC, including production and later operating and support costs.

This tends to contrast with the Joint Service Agreement (Ref. 3) on how DTC is to be approached:

> "Design-to-Cost is a process utilizing unit cost goals as thresholds for managers and as design parameters for engineers. A single average 'Unit Flyaway Cost' goal is approved by DSARC for the program. This goal is then broken down into unit production cost (UPC) goals by the Program Manager and provided to each contractor or in-house source for the appropriate major subsystem. The dollar value for each goal represents what the government has established as an amount it can afford (i.e., is willing and able) to pay for a unit of military equipment or major subsystem which meets established and measurable performance requirements at a specified production quantity and rate during a specified period of time.
>
> "Unit production cost, schedule, and performance goals must not be achieved at the expense of life cycle cost."

Now one sees why DTC has addressed primarily UPC and made LCC merely a secondary consideration. In this context, LCC is

defined to include research, development, test & evaluation (RDT&E) as well as UPC and operations and support (O&S) costs.

Other highly placed sources within DOD have written:

> ". . .design to a price means that DOD will establish a unit production price that the defense budget allows and reflects the military value of the equipment. Attainment of that price will be made a criterion of procurement." (Ref. 4).

In this case DTC addresses only UPC.

This seeming lack of coordination and understanding at the highest levels of DOD management has done little to aid the practitioners in the field. One now finds individual projects defining cost goals and their attainment in any manner convenient.

Obviously, from a cost control standpoint, there must be some sort of balance between UPC and overall LCC. What this is and how it is achieved has never been authoritatively stated.

C. REQUIREMENT FOR IMPLEMENTATION OF DESIGN-TO-COST

Department of Defense Directive 5000.1, (Ref. 2) formally prescribes a new approach to weapons procurement. General policies were revised for all major systems. In addition, specific actions and guidelines were delineated for a new acquisition cycle. These guidelines included the requirement to implement DTC.

This implementation of DTC has been the subject of considerable uncertainty and controversy and is examined in this study in detail.

II. HISTORY OF EVENTS LEADING TO THE REQUIREMENT FOR DESIGN-TO-COST

The historical background of events leading to the institution of DTC and other procurement changes are discussed in this section.

A. McNAMARA PHILOSOPHY

During the middle 1960's the Department of Defense operated with Secretary McNamara's Planning, Programming, Budgeting (PPB) system. Under this structure the services were directed to meet their worldwide commitments in a "cost effective" manner. Little, if any, fiscal guidance was given to the military planners. Program directors were given no explicit spending ceilings (Ref. 5). McNamara, himself, stated: ". . . the United States is well able to spend whatever it needs to spend on national security" (Ref. 6). The overall defense budget was to be sized to meet whatever foreign policy objectives were sought.

Service planners often found it difficult, however, to obtain force level increases from the Office of the Secretary of Defense (OSD) or Congress. For this reason, the military planners then demanded the highest possible performance from such weapons as were available. Designers were encouraged to continually advance the technical state of the art. Increased performance became the only real goal and was sought at the expense of all else (Ref. 7).

This era also saw the advent of the total package procurement concept. The entire acquisition of a system, from basic R&D to final production, was to be accomplished under one fixed price contract. The commercial world had shown this to be a viable approach for a relatively simple product, to be produced in a short period of time, and when complete and accurate specifications were available. The contractor must know exactly what is expected and how he will produce it. Unfortunately, this type procurement procedure did not produce the results expected of it for major weapons systems. Difficult and conflicting demands resulted from questions of cost, complexity, or even feasibility. Contracts were awarded to the lowest bidders, in some cases the most desperately in need of business. When their efforts faltered, they then turned to the government to be bailed out of disaster. While nice in theory, this approach just did not work out in practice (Ref. 8).

Policies revolved around one critical assumption, the availability of adequate funding. Planners needed to concern themselves only with avoiding waste or overly provocative actions. Recent history and present Congressional mood have subverted this assumption. Budget cuts are becoming increasingly restrictive. Almost half of what money does remain in the DOD budget goes into escalating personnel costs. Indeed, the future looks quite forbidding.

B. COST GROWTH

While it is universally known that weapons costs have escalated steadily during recent generations, controversies have tended to center about aspects of this cost growth that relate to policy and procedures. A recent study of these cost areas, commissioned by Congress and conducted by the Comptroller General (Ref. 9), outlines three major causes of cost growth: improved weapons capability, inadequate cost estimating ability, and requirements changes.

1. Improved Capability

With the advancement of technology, new weapon systems are constantly being developed, seeking wider and increased performance capabilities. Resultant increased costs, however, do not necessarily imply proportional performance increases. Table I shows cost/thrust ratios for jet engines since 1956.

TABLE I

COST AND PERFORMANCE DATA RELATING TO AIRCRAFT ENGINES

Aircraft	Deployment Year	Max. Engine Thrust (lbf)	Cost Per Engine ($ Millions)	Cost Per Pound of Thrust
F-86H	1953	8,920	.34	$38.10
F-100E	1956	16,000	.27	16.90
F-4E	1967	17,900	.24	13.40
F-15	1972	More than 23,000	1.00	43.50

(FY 1974 Dollars)

Figure 1 displays the results of studies of aircraft cost increases related to their respective performance gains. Even in constant dollars, cost increases appear to outgain system performance.

REPRESENTATIVE RELATIVE INCREASES IN COST AND PERFORMANCE FOR THIRTEEN MAJOR SETS OF AIRCRAFT WEAPON SYSTEMS SINCE WORLD WAR II

	COST		PERFORMANCE					
COST OR PERFORMANCE FUNCTION	R&D COST	UNIT COST	PAYLOAD	RANGE OR ENDURANCE	SPEED	AVIONICS	CREW COMFORT & SAFETY	DELIVERY OR NAVIGATION ACCURACY
FACTOR OF INCREASE	5.4	4.2	2.3	1.9	1.8	3.0	3.0	3.0

NOTE: FACTORS OF INCREASE ILLUSTRATE THE PROPORTIONAL INCREASES OF SPECIFIED COSTS OR PERFORMANCE PARAMETERS FOR NEW WEAPON SYSTEMS OVER THOSE BEING REPLACED. THESE FIGURES REPRESENT THE RESULTS FROM 13 WEAPON SYSTEM STUDIES FOR AIRCRAFT DEVELOPED SINCE WW II.

FIG 1

2. Inadequate Cost Estimating Ability

The inability to estimate costs often results in cost overruns. In order to avoid confusion surrounding the many various definitions advanced by persons with various viewpoints, the description assigned by the Comptroller General will be applied. Cost overruns are the difference between projected or "advertized" costs for a weapons project and the actual costs incurred by the public. Cost overruns are related primarily to three cause factors (Fig. 2). It is to be noted that current estimates at the time of this study (30 June 1972) dealt with systems still under development, hence all related total program cost increases are not yet included. Estimating errors due to technology, comprising about 25% of the total overruns, are due largely to the push for performance, technical state of the art, and overoptimism on the parts of both contractors seeking business and services

seeking program approval. The second major source of estimating error is related to inflationary cost increases, in most cases out of the control of both contractual parties.

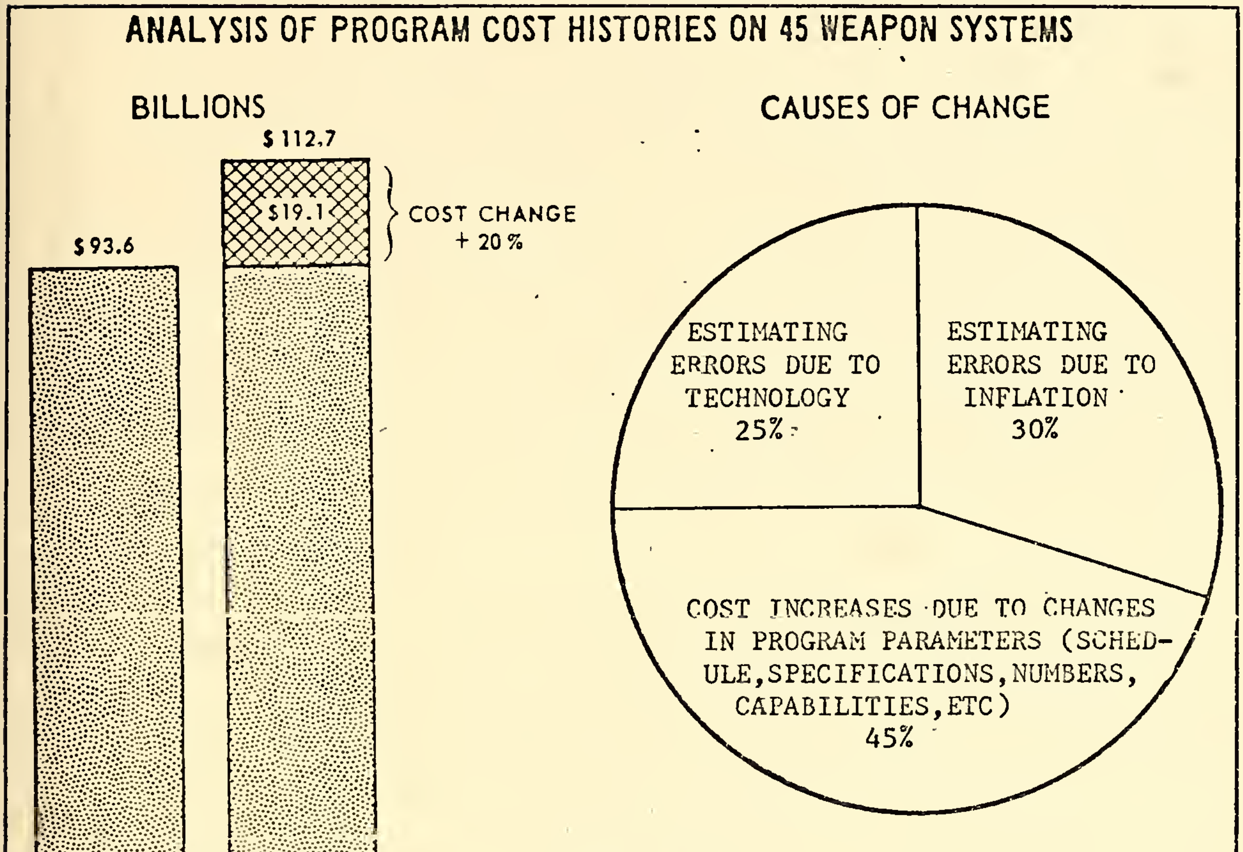

FIG 2

3. <u>Requirements Changes</u>

The largest cause of cost overruns is unforeseen changes in requirements. These program changes may be due to revisions of specifications relating to overly ambitious performance goals and associated state of the art type technological roadblocks. Other changes have historically been found in alterations to schedules, due either to unanticipated

delays or accelerations. Procurement numbers may suddenly face drastic cuts, thereby sharply increasing costs per copy. These actions have been most noticeable in cases where production has been concurrent with development. Finally, there is the costly engineering change proposal (ECP) resulting from changed requirements or threat scenarios, demanding upgraded performance. Unfortunately, however, many ECP's can be traced to poorly developed, ambiguous, or inadequate specifications. Again, concurrent production is hardest hit by these costly retrofits. The C-5A doubled its projected costs within less than a five-year period, while another study of some twelve major systems showed current estimates equal to 3.2 times the original estimates.

C. EFFECTS OF RECENT TRENDS IN WEAPONS PROCUREMENT

The increasing complexities and costs related to weapons procurement have had numerous dangerous effects upon military combat readiness. These are explained in the following paragraphs:

1. Fewer Weapon Systems Acquired

Increased program costs, coupled with decreasing budgets, have led to massive reductions in the numbers of items procured. This trend is illustrated in Table II. These fewer weapons procured by DOD can have severe effects upon national defense posture. A system that can be deployed in only one-third the numbers as its predecessor must then be at least three times as effective just to break even. Even then, the supposed benefits of costly new systems aren't realized.

TABLE II

PROGRAM REDUCTIONS RELATED TO PROGRAM COSTS

System	Original Quantity Planned	Original Program Cost Projection ($ Millions)	Current Quantity Planned	Current Program Cost Projections ($ Millions)
C5-A	120	3,423.0	81	4,526.0
DLGN-38	23	3,980.0	5	820.0
F-14	710	6,166.0	313	5,272.0
F-111	1,388	4,686.0	466	6,994.0
LHA	9	1,380.3	5	970.0
MARK-48	(a)	720.5	(a)	1,957.9
SAM-D	(a)	4,916.8	(a)	5,240.5

(a) Classified

2. Increased Weapons Complexity

The more complexities built into increasingly sophisticated systems, the more possible areas for failures. Down-times due to each failure increase with complexity and sensitivity. This translates to fewer up systems available at any time. These fewer systems ready simplify enemy targeting or evasion problems.

3. Reduced Training

Field commanders, faced with conserving these costly assets, will in many cases reduce training. Military readiness is thereby even further degraded.

4. Excessive Optimism

These problems have also had undesirable effects upon industry. With procurement curtailed and fewer contracts let, excess productive capacity increases. Competitive pressure

grows as companies fight ever harder for the few remaining contracts. This, in turn, leads to undue promises of system capabilities. To stay afloat, unrealistic cost estimates may be submitted to "buy into" contracts.

5. Loss of Public Confidence

As a result, costly program failures or bailouts have occurred, which have received wide attention in the press. Loss of public confidence is mirrored in increased Congressional pressures.

6. Excessive Management Restrictions

Ever increasing numbers of rules and rigid policies result from efforts by Congress to interject itself into day-to-day management decisions (Ref. 10). The able people available find themselves hamstrung by inflexible guidelines. It is felt that the talented people are there, but better training is needed. Experience has shown these people can function when a critical project must be done expeditiously, but the bureaucracy must often be bypassed in these cases (Ref. 8).

The adversary environment that has grown up between DOD and Congress must be dispelled. Regained cooperation and understanding is vital to any improvements.

III. INTRODUCTION OF DESIGN-TO-COST TO THE DEPARTMENT OF DEFENSE

In mid 1971, Design-to-Cost was formally imposed by OSD as part of a series of sweeping changes to DOD procurement policies. In order to place DTC into its proper context with other reforms, a review is made of implementing directives and their impact upon Navy procurement. The directive initiating these procurement reforms, DOD Directive 5000.1, and the Joint Design-to-Cost Guide, representing the services' interpretation and reply to DTC are examined. Actual implementation of DOD Directive 5000.1 within the naval establishment by SECNAV Instruction 5000.1 is detailed. The authors describe the basic philosophical changes required within DOD to adopt DTC and then compare these ideas with current commercial practice. The setting of cost and performance goals and resultant tradeoffs are explored. Finally, a brief survey is made of reactions by DOD and contractor personnel to DTC and its implementation.

A. DOD DIRECTIVE 5000.1

This directive (Ref. 2) represents a major change in DOD procurement strategy. Providing overall policy guidance for all major acquisitions, it has been known as both the Bible for DOD procurement and David Packard's legacy to defense system management (Ref. 11).

Coverage of this directive encompasses all major programs. Such programs are herein defined as having either projected

RDT&E costs in excess of fifty million dollars, or production costs of greater than two hundred million, or any other specified programs of national urgency. In addition, the management principles are declared applicable to all programs. These management principles are not clearly defined here. The question arises, for example, as to whether DTC must be applied to small programs whose size is below the thresholds listed above. Interviews with program administrators at NWC China Lake indicate this may not be the case. Other reputable sources, however, claim that DTC must apply to all items in defense inventories (Ref. 12).

One major thrust is toward decentralization of power and decision making authority to the maximum extent practicable. This contrasts strongly with tight McNamara era central control (Ref. 13). Individual program managers are to be granted broad authority to accomplish assigned objectives. Levels of supervisory authority are to be minimized. The presently heavy paperwork and reporting requirements laid upon these managers will be reduced, giving them more time for their primary duties. The assignment, tenure, incentives, and rewards of program managers are to be made a subject of direct concern to DOD component heads. The primary burden of defining needs, developing systems, and source selection is shifted to the individual services. OSD now provides only such overall policy guidance and supervision as is necessary. Major decisions regarding scope and direction of programs are made by SECDEF with the aid of the Defense Systems Acquisition Review Council (DSARC).

The DSARC cycle (Fig. 3) provides a general format for the acquisition process. Sweeping in nature, attempts have been made to avoid unnecessary restrictions and rigidities upon the various kinds of programs. Specific development phases are identified. Each phase is then followed by DSARC review before the process is resumed. These phases and reviews are described below.

The conceptual phase makes use of independent basic and applied research. These studies are handled by the individual services which will direct initial activities as they deem appropriate. Efforts are confined largely to paper studies. The Development Concept Paper (DCP) is the final product of this phase, providing a brief (about twenty-page) summary of the proposed system. Included is a general statement of needs or threats, performance objectives of a countering system, alternative approaches available, the potential problems/risk areas associated with each, and an overall procurement strategy. The DCP is presented to a first DSARC review, DSARC I, which recommends whether or not continued development is warranted. If so, program thresholds are delineated for later phases.

The validation phase involves paper and hardware studies to determine feasibility of proposed ideas. The results are again presented for review to DSARC II where needs, LCC estimates, risks, and full-scale development plans are reviewed.

Full-scale development involves final design engineering efforts, resolving risk areas and putting the whole

THE DEVELOPMENT PROCESS FOR A MAJOR WEAPON SYSTEM

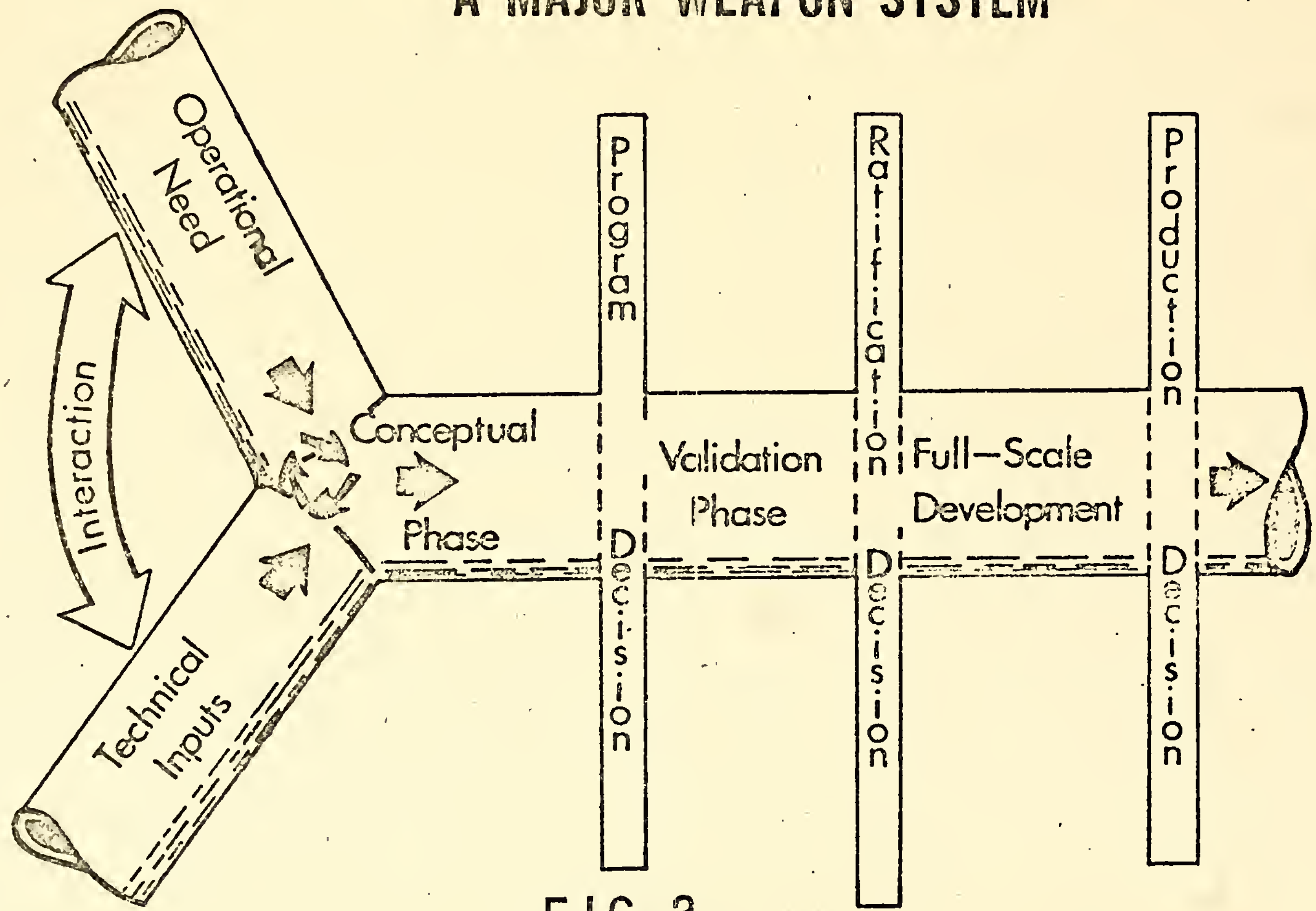

FIG 3

system together. DSARC III again reviews needs, costs, and benefits and then provides final fiscal guidance before production is commenced.

As mentioned earlier, LCC has been declared a primary design parameter by DOD Directive 5000.1. Tradeoffs are conducted among costs, performance, and schedule to assure efficient procurement. Methods of tracking estimates and costs must be provided, using, as much as possible, the contractors' own management information systems.

In order to better define risk areas and their solution, reliance is placed upon actual hardware testing, rather than paper studies. This entails greater emphasis upon building mockups and actual prototypes, greatly increasing planning confidence.

Contracting procedures are also changed. Total package procurement is banned. Each phase of development now involves separate contracts. Development contracts are of a cost reimbursement type, while production is of a fixed price nature. Any ECP must be costed before approval.

These policy guidelines reflect David Packard's personal management philosophies, providing low level responsibility and freedom with but general guidance from on top (Ref. 14).

B. JOINT DESIGN-TO-COST GUIDE

DOD Directive 5000.1 required implementation by the services within 90 days, however, final agreement by the services on a joint design-to-cost guide took well over two years. The result is still only a general approach to the DTC

problem (Ref. 3). Primary cost emphasis is shifted to UPC, giving LCC only passing attention.

Specification of performance requirements for any developing system involves a series of targets and thresholds. Targets indicate desired goals while thresholds represent minimum allowable performance. Tradeoffs are then conducted within these bounds in efforts to achieve target levels. Emphasis has changed from cost justification to cost reduction.

Greatly increased flexibility is required. Once cost and performance thresholds are established, latitude must be given to program managers and contractors to allow tradeoffs of cost, performance (including maintenance and reliability), and delivery schedule. Specifications reflect desired results rather than detailed "how to do it" directions. Design iterations involve tradeoffs to meet these thresholds. Development funding must be related to anticipated lower production costs.

Cost goals currently include recurring and non-recurring production costs. This is in recognition of state of the art limitations for LCC. Continued pursuit of this technology and its use is encouraged. During the conceptual phase these cost inputs result from cost analyses supplemented by empirical CER research. The average unit flyaway cost goals of DCP become official after DSARC approval. Once set, they may be changed only by SECDEF following another DSARC review. During the validation phase the contractor and program manager seek optimum designs through tradeoffs and other improvements. Combinations of industrial engineering and

parametric cost estimates provide firmer cost data. DSARC II is the latest time at which cost goals may be set. Obviously, the later cost imputs are made, the smaller will be the effects they will have upon designs.

Critical to the entire program are the realism of cost and performance goals. Goals too easily attainable are wasteful. On the other hand, standards set too high, especially in the area of costs, may destroy motivation or result in ineffective systems. To assess progress a tracking process is necessary, both for up-to-date feedback and as a historical record. This is normally done by standard work breakdown structure (WBS) format as contained in MIL STD 881. Formats of required reports are also specified.

The contractual agreements provide the basic interface between buyer and seller and, as such, have been given special attention. Cost reimbursement contracts are to be written for conceptual, validation, and full scale development phases. Initial production entails fixed price incentive with later buys requiring firm fixed prices.

The basic criteria for these contractual relationships require legal enforceability. The contractor must have flexibility to make necessary tradeoffs. Means must be provided for tracking and enforcement of thresholds. Finally, motivation and incentives must be provided to ensure a task is done properly. The requirements for each phase differ considerably. Early conceptual studies do not normally have rigid cost goals. Instead, the emphasis is upon gathering data for later goal establishment.

The validation phase request for proposals (RFP) sets goals for both cost and performance. Specifications are limited to only those essential for output definition. Other information to be provided includes risk specification as currently known, configuration compatibility requirements, schedule, employment scenario, and source selection criteria. Contractors are required to provide supporting data to back up estimates. The degree of flexibility afforded contractors depends directly upon the competitive climate. At any rate, source selection promises to be more difficult with increasing design freedom. The contract during this time must address the above goals, tracking procedures, and escalation factors as well as necessary incentives. These incentives are not normally needed in competitive situations. Otherwise, an award fee may be deemed appropriate.

Full scale development should include as much competition as possible. In many cases this may not be feasible. At any rate, the basic design configuration becomes more firm, allowing goals to be set for various subsystems. Contracts now become more explicit in their requirements and flexibility diminishes. Special attention can now be given to tracking procedures and any required incentives. The incentives needed depend upon the level of competition. Incentive or award fees in the range of three to five percent may be needed if no competition exists.

Initial production should be priced at DTC targets determined from the development phases. This is indeed the

test needed to determine whether DTC goals have been actually achieved. Tracking of costs should again use the contractor's management information system (MIS) as much as practicable.

C. SECNAV INSTRUCTION 5000.1

The Navy's formal reply to DOD's sweeping procurement reforms came in March of 1972 and provided a far more detailed and specialized guidance (Ref. 15). Due emphasis was given to maximum practicable decentralization of authority and responsibility. Emphasizing flexibility, any unnecessary restrictions on management are to be avoided. Program charter authority is granted by the Chief of Naval Material, normally to a Systems Command (SYSCOM). Chartered program managers hold the rank of at least captain/colonel. Bounds of authority are explicitly stated in the charter. Any instructions from program managers must be passed via contracting officers. Field activities and laboratories are tasked with providing necessary support.

Cost parameters address LCC goals and are equal in importance to technical inputs. Again, tradeoffs are required between all these factors. In addition, consideration is given to impacts upon the national economy. Cost estimates follow the MIL STD 881 format to third level WBS elements. In addition, operational and integrated logistic support (ILS) data is introduced as appropriate. All estimates are subject to the reviews of another disinterested organization. Any discrepancies or disagreements must be worked out before the project may proceed.

Industrial aid should be solicited in drawing up RFP's. Special care must be given, however, to protect any proprietary data. Technical transfusion is promoted only where necessary. This may be done by encouraging joint agreements between companies. Such cooperation is not mandatory. Finally, full understanding by industry of tradeoff factors and competitive selection criteria is absolutely essential.

Tracking procedures are in accordance with Cost/Schedule Control Systems Criteria (C/SCSC).

D. PHILOSOPHY CHANGE

The reforms described above involved a difficult transition for the services. DOD Directive 5000.1 was issued on 13 July 1971 and allowed only ninety days for implementation. SECNAVINST 5000.1 was issued 13 March 1972, some eight months later. This document still addressed DTC largely in generalities. The Joint Design-to-Cost Guide was finally completed on 3 October 1973, nearly two years later than specified by OSD. The Guide admits: "Its basic intent is to identify what should be done with only a general approach of how to do it." Ostensibly, this would allow a great deal of flexibility. In actual practice, however, this has resulted in widespread confusion and uncertainty. The several authoritative sources still have not agreed upon how to use LCC in the determination of the DTC goals. Motivation to design to LCC is reduced since DSARC has agreed to accept UPC targets. In the background remains a large degree of skepticism as to whether the concept is even viable (Ref. 11). In this

environment of stated generalities and uncertain direction the individual projects must grope along by themselves.

The recent emphasis upon cost is a foreign concept to DOD procurement. Traditional imputs to programs came largely from technical and intelligence communities. Cost was not a major factor. Today, however, costs may have become the dominant consideration (Ref. 16). Emphasis has shifted from merely justifying cost increases, to their reduction or total elimination. Perhaps most notable is the shift in ideals away from providing the best weaponry possible (Ref. 7). Rather than specifying the highest performance attainable, goals are set in bands with minimum acceptable output levels as the lower end and the desired performance characteristics at the upper end. Tradeoffs are made for any improvements between these levels.

Decentralized decision making authority is a major departure from PPB tradition. As a result, individual project managers are to be given increased influence to accomplish their program objectives. Managers now have the authority to approve tradeoffs in technical and financial areas as contractors proceed with design iterations. Another result is the reduced paperwork and reporting requirement. This should now allow more time for these added management activities. Many of the diverse problems that now habitually arise do not have precise, school-type solutions. Greatly increased status for the project manager is needed to meet these challenges. Program managers are still bound by overall policy.

All instructions from managers must be formally passed by appropriate contracting officers. In the case of any disagreements concerning policy, the decision of the project manager is regarded as binding, pending appeals (Ref. 15).

Specification procedures are changing drastically in nature. Rigid "how to do it" specifications are being reduced in number to the minimum necessary. Instead, information is provided concerning desired performance goals. Minimum performance levels set by DSARC may not be violated without DSARC review and formal OSD approval. As mentioned before, tradeoffs must be made above these minimum levels to achieve increased efficiency. This is the most critical area for cost reductions. All ECP's must be priced before they are considered for implementation. A historical inability to make these tradeoff decisions was instrumental in the serious problems faced by programs like the C-5A and MBT-70 (Ref. 17). Performance specifications such as these now being implemented in DOD have been common in commercial industry for many years, and have helped guarantee the manufacture of desired products (Ref. 18). This specification procedure has provided the necessary freedom for designers to explore innovative approaches to problems. Special care must be applied in drawing up requirements and clearly specifying what is needed. Outputs must be quantifiable. In addition, criteria for weighting tradeoff areas must be stated unambiguously.

Competition has received a new emphasis in DOD procurement. Competitive motivations have been recognized as the

most important driving force in the commercial world (Ref. 18). Past reliance upon total package procurement tended to disregard this idea. Initial competition existed for source selection; however, as the project progressed, problems often appeared, relating either to limitations of the designer-producer or to his approach. Having no other alternative, the buyer was faced with having to live with the situation as best he could. In addition, total package procurement did not allow a wide measure of specialization, as may be found in the different types of companies now in existence. Instead, only one company was designated to handle all the varying demands and requirements, both technical and managerial, as a major project moved from conception to full production. Design-to-Cost philosophy seeks to extend competition as far as possible in the procurement cycle. Hardware competition may be extended throughout development phases. The "fly before buy" approach permits a direct comparison of prototype performance, eliminating much analytical guesswork and error involved in selection of proposals (Ref. 19). Separate contracts should be negotiated for each phase of development and production (Ref. 9). In this way, the developer of a system is not necessarily guaranteed the following production contract. This increasing emphasis upon competition is expected to have profound effects upon contractor motivations and attitudes.

Competition and tradeoff analysis requires increased investments of both time and money. This competition often

involves substantial duplication of efforts, requiring large financial outlays. These outlays should be in the form of cost reimbursement type contracts. Fixed price contracts tend to limit long, detailed, and expensive tradeoff analysis. It is felt that very large profit incentives, perhaps as high as twenty to twenty-five percent, may be justified for meeting DTC goals, in order to reduce long term overall costs (Ref. 20). Development timetables must be extended, especially in early stages, in order to adequately explore technical risk areas. Experience has shown that corrections required to rectify problems escalate rapidly in both time and cost as development proceeds. The costly nature of delayed changes greatly reduces tradeoff capability.

E. COMMERCIAL APPLICATION

The introduction of DTC into DOD procurement policy has been looked upon as simply borrowing a page from the notebook of commercial industry (Ref. 7). The business world, where money is truly a scarce resource, gives a detailed cost analysis to all its actions. Thus, DTC may be regarded as intrinsic to civilian industry. Lessons derived here from long experience may serve as valuable aids for introducing DTC into government procurement.

In a growing industrial economy, companies are often faced with having to acquire new or specialized products which are not available "off the shelf." In order to meet these needs, the requirement is first stated in the most general of terms. This action allows focus upon what general

type of product is needed. Prematurely locking into a specific approach may thereby be avoided. Specifications are then drawn up to meet these needs. These specifications may be very precise in nature and involve detailed drawings, blueprints, and specified materials. In some cases, even a set of required production techniques may be specified. These detailed requirements have been found to be most suitable for relatively simple items. Since these specifications are given to the producer, the burden for proper design is placed upon the buyer. He has no guarantee of satisfactory product performance. At the other extreme, one finds generalized performance specifications. These may consist of little more than a "black box" with designated inputs, outputs, and interface parameters (including size, maintenance, environment, etc.). This specification format is especially useful when a proposed product is not well defined. The burden for proper design in this case is now placed upon the seller. Guaranteed performance may thus be assured.

Ultimate cost considerations are an early program input. These considerations may hinge upon the potential market value of the product, value to the buyer, or upon some arbitrary budgetary limitation. These limits are not necessarily the same. Competition may also influence cost levels. Additional considerations of performance and delivery schedule have a bearing upon ultimate source selection. Competitive negotiations are then commenced to determine this source of supply. The search for suppliers may include internal as well as

outside sources. The final decision is based upon which supplier can provide the greatest overall benefit to the buyer. No other restrictions should be allowed (Ref. 18).

The commercial world views DTC as management of design, development, production, and "life support" expenses in such a manner as to meet a marketplace value to a user (Ref. 19). Design engineers must conduct their work in anticipation of future market environments as well as meeting today's needs. Special emphasis is given to areas of technology, product value, projected price levels, and competitive market structure. Competition may extend through the entire procurement cycle, from initial conception to follow-on parts and service. Responsiveness to meeting the needs of a buyer provides the only hope of financial rewards. The competitive market allows the buyer to take his business elsewhere if one selected producer cannot perform. Competition is thus a powerful driving influence toward efficient practices.

As the development of a product progresses, several decision parameters come under consideration. These include design requirements, cost estimates, tradeoffs between them, and general resource allocation. The project manager is responsible for all these areas except the last. Higher management deals with resource allocations and conducts periodic reviews of project team efforts, comparing them with overall corporate goals. Because of the diverse nature of these responsibilities, it is important that project managers be flexible and well trained to handle them. Tradeoff decisions made by project management are crucial to overall

project success. It is important that the project manager be responsible and have direct access to top level management. High level support, understanding, and trust are essential to the continued well being of project team efforts.

The membership of the project team is normally hand selected to be small, highly competent, and cohesive. The different personalities and talents must be integrated into a team capable of acting quickly and decisively regarding new and constantly changing information. Engineering provides technical inputs concerning what can be made and how to make it. Marketing provides information concerning what can be sold. The comptroller's office provides overall financial constraint data. These inputs provide a data base for design changes and iterations. These changes may include slight modification of an existing plan, or they might entail sweeping conceptual revisions. The team constantly probes for possible modifications to performance, cost, or schedule. Nothing should be regarded as untouchable.

Personnel policies are regarded as a key to overall project team success. To maintain coherency, management changes are avoided, especially during major development phases. If, for some reason, the manager must be replaced, the successor is chosen from within the team membership. Other promotions will stay within the development team as much as practicable. In this way a true team identity is formed. The knowledge and experience derived as projects develop are conserved and membership can keep abreast of the latest happenings.

It would appear that DTC, as applied in commercial business, has several policy ramifications that ought to be given careful consideration within DOD.

F. GOALS

The setting of quantifiable performance objectives relating to a proposed weapons system and the determination of measurable costs to be incurred in maintaining such performance objectives is at the heart of any complete weapons system analysis (Ref. 21). Realistic, but challenging goals are essential. If too easily attainable, industry is not sufficiently challenged to produce its best efforts. Unrealistically stringent thresholds, on the other hand, will destroy motivation to produce anything useful. The manner in which performance and cost goals are selected is briefly examined below.

1. Performance Goals

The intent of any major weapons system procurement is to provide a countermeasure for a specific threat. Because of the diversity of systems developed, and the problems they address, it is not within the scope of this research to attempt to draw up a comprehensive set of guidelines for all cases. Detailed design specifications are being replaced by comprehensive performance requirements. Two major considerations in the selection of these performance requirements stand out: Are such goals achievable? Are such goals affordable? A third consideration seeks to avoid large increases in marginal costs for a relatively small increase

in performance level. In order to intelligently assess these areas, a wide diversity of inputs will be required to determine system parameters. These inputs must come from industry sources as well as government planners. Such a partnership will avoid many of the limitations facing each party individually. Technological and operational complexities have grown so great that no single institution can go it alone.

2. Cost Goals

As noted earlier, cost has not always been an initial parameter in the definition and selection of weapons systems. The imposition of cost parameters has revolutionized procurement strategies. Several types of growing pains have accompanied this transition period. There seems to be a general agreement within the upper echelons of DOD that cost goals should be determined by system average unit costs. The makeup of this cost goal has been the subject of confusion and controversy. DOD Directive 5000.1 declared that LCC should be the ultimate DTC goal. In practice, however, UPC has become the goal. Such actions have met the approval of DSARC. Some thinkers feel that designing to UPC implies simplicity and thereby contributes to lower LCC (Ref. 12). Other sources disagree (Ref. 22). Approaches to even UPC have been found to vary considerably. As shown later, UPC may include both recurring and non-recurring costs. Other cases included only overall recurring costs. Still other cases addressed only recurring hardware costs. Even non-recurring costs have been subject to manipulations (Ref. 23).

It is apparent that no meaningful contract may be drawn up without clear agreement by all parties involved as to the precise makeup and definitions of cost goals (Ref. 12).

A variety of methods has been proposed for setting cost goals. One such approach sets the price at the same level as the system to be replaced, challenging designers to use improved technology to come up with a better product. Such a goal is arbitrary and there is no reason to believe that this is actually the optimum price level. Akin to this approach is the determination of the total budget available for a system type and the number of systems needed. One simply divides the budget by the number of systems to define unit costs. Again, such costs are arbitrary in nature. The industrial engineering estimate has historically been used to define the costs of a complete system from a "ground up" approach. This approach attempts to identify and cost all items comprising a proposed system, operations involved in putting it together, and any other costs related to deployment. Obviously, a great deal must be known about this system before such an approach may be used effectively. This is not possible for a new and undefined system. The historical cost of a system analogous to one being proposed may be helpful in some cases. This similarity in cost, however, can be no better than the analogy between systems built at different times and under different conditions (Ref. 24). Late 1971 saw the imposition of parametric cost estimating procedures upon DOD (Ref. 25) in an effort to capitalize upon past experiences.

Parametric CER's attempt to relate performance and technical parameters of a proposed system to a projected cost level. These relationships are developed from regression equations based upon historical data. The equations, themselves, are developed through trial and error curve fit to this empirical data. Although still a relatively new art, cost estimating accuracies within ± 10% may be attainable (Ref. 9). Interviews with members of the Cost Analysis Division at NWC, China Lake indicated that such optimism may be premature. Practitioners in the field are currently satisfied with estimates within 20 to 30% of actual cost. Nevertheless, these estimates are vastly superior to 200 to 300% errors resulting from earlier "ground up" cost approaches (Ref. 9). Aggregated historical data includes actual experience and includes many costs often ignored by older techniques (general administration, profit, maintenance & support, personnel training & equipment, service personnel, test & evaluation, systems engineering, reporting data, initial spares, overhaul, etc.). Historical data includes past failures and problem areas, while industrial engineering approaches tend to be more optimistic. Furthermore, parametric CER's provide data concerning cost uncertainty and confidence levels, rather than solely providing precise, but incorrect solutions.

Parametric CER's furnish their greatest benefits during the earlier stages of development (Ref. 26). Early conceptual studies have little, if anything, in the way of true design information. Application of CER's provides rough

cost envelopes to aid in design selection. Consistent relationships allow direct comparisons between alternatives. Ease of rapid programming is helpful in tradeoff sensitivity analysis. The cost goals postulated from this stage promise to be more realistic than heretofore. As the design progresses, an overall WBS begins to take form, providing a framework for subsystem study. Tradeoff sensitivities relating cost and performance of components may now be examined. These estimates aid in selecting overall design configurations. Comparisons can be made between CER's and industrial engineering approaches to check the validity of each. Agreement results in increased confidence in both estimates. Any areas of disagreement can then be studied and resolved.

The major difficulty associated with developing CER's is the acute shortage of necessary historical data (Ref. 26). This is due largely to accounting procedures. Life cycle estimates are especially hard hit by this problem. Only aggregate information is available. Effects of program changes (schedule, ECP, etc.) cannot normally be isolated. Proposed CER's can be verified only against competing CER's or industrial engineering techniques. Much has to be learned here.

Several criticisms are leveled at applying the CER approach. In most cases the aggregated information cannot be directly related to subsystems. Prior inefficiencies may be perpetuated, rather than corrected. Most disturbing, there does not appear to be any analytic relationship to

real life occurrences. To the layman this approach may appear to be an application of statistical analysis to draw a mathematically precise line from an unwarranted assumption to a foregone conclusion. Perhaps the best defense of the CER approach is that, in spite of all its intellectually aesthetic shortcomings, it does seem to work.

Cost information, from whatever source, is now a major criterion in determination of overall system desirability. To be truly effective, cost considerations should be included in the DCP (Ref. 27). Cost is thereby made simply another system parameter. The insertion of any such parameter, after design has begun, adversely affects efficiency. Several sources of independent cost estimates are being developed. Each weapons project office is tasked with developing its own estimate. In addition, government laboratories may provide assistance to projects and help to validate these estimates. Each service follows with its own cost estimate. Finally, DOD has formed its own cost estimating organization, Cost Analysis Improvement Group (CAIG), to aid DSARC in its review capacity. The many autonomous groups within DOD that are developing independent CER capabilities should aid in the rapid development of a realistic cost projection capability.

G. TRADEOFFS

The area of tradeoffs between various development parameters is the most distinguishing feature of the DTC approach. This new tack should not be confused with the established

policy of Value Engineering (VE). Past application of VE has attempted to define lower cost approaches to perform a given function. Output performance was not normally permitted to vary. Introduction of DTC has made cost an equal parameter with output. Both cost and performance may be traded off with one another to achieve a more efficient overall approach (Ref. 18). Minimum performance levels, however, are not to be compromised. Specifications defining these minimum levels must be justified before inclusion in RFP's and contracts (Ref. 27). Overall costs, facing a similar constraint, are now limited to a maximum ceiling which cannot be violated (Ref. 28).

Wide ranges of flexibility should be available to contractors. Broad performance specifications, rather than detailed blueprints, are being used to define weapons systems. Any remaining use of MIL SPECS must be fully justified (Ref. 27). Contractors are tasked with providing a large measure of their own cost-benefit analysis. Little textbook type information is now available. Each project presents unique problems. Intelligent and decisive leadership is critical to both contractor and DOD personnel. Project managers must be well trained, capable, and experienced in order to cope with wide ranging responsibilities. New proposed tradeoffs must be reviewed quickly by a higher management which is responsive to change.

Industry must be fully informed concerning the bounds of its freedom and how best to apply it. The various requirements

must be ranked in some manner. Contractors may find themselves attempting to make operational type decisions. Relationships must then be provided so that designers can correlate marginal costs with marginal benefits. The Government is tasked with specifying the marginal benefits for each area of tradeoffs (Ref. 29). Continued close communication with DOD will be needed throughout development in order to understand and expeditiously dispose of tradeoff proposals (Ref. 12).

A system must be set up for defining who is responsible for making and approving each particular type of tradeoff. Such a rule should make allowances for the size and nature of changes. Levels of tradeoff approval may be as low as the contractor or project manager, for relatively minor revisions. On the other hand, OSD approval may be needed for major changes in parameters. Review authority should be no higher than that needed for an adequate judgement of benefits (Ref. 29). Consideration must be given, however, to the cumulative nature of changes. A large number of minor alterations may in fact have results of major proportions.

Another important area of tradeoffs deals with early R&D expenditures as opposed to other components of LCC. Greater investments in early program phases would tend to help lower later costs through continued design improvements. There is a point, however, where the marginal benefits of such R&D expenditures will decrease. Finally, a point will be reached where further investment costs are not offset by reductions

other LCC elements. Investment beyond this point is wasteful. At present there does not appear to be an explicit solution to this problem.

The benefits of commercial world experience seem to have been helpful. Those contractors with a history of dealing largely with a commercial market for their sales tend to be more cost conscious. This has been demonstrated by a better capacity to make intelligent tradeoff decisions (Ref. 21). The Government must now attempt to force this cost conscious attitude upon all its suppliers. Easy money days appear to be gone forever.

H. REACTIONS TO IMPOSITION OF DESIGN-TO-COST

The response to the compulsory introduction of DTC upon DOD procurement has been mixed. Interviews held with program engineers and administrators at NWC, China Lake seemed to indicate that reactions to DTC depended largely upon the stage of program development. Those projects which saw the addition of DTC requirements in early conceptual stages viewed it as just another design parameter. This requirement presented an engineering challenge and, as such, was well received, once developers saw cost as a valid constraint. Those programs which have moved farther along in their evolution and had DTC applied retroactively viewed it less favorably. Designs have, in many cases, become firm. Long range planning has been laid out. Proper implementation of DTC would require a whole new development effort in order to optimize cost along with all the other constraints. Suddenly changing the rules

after the game has begun was viewed by some as unnecessary harassment. As such, DTC has received little more than lip service in these cases.

Civilian contractors have, in some cases, modified their management approaches to accommodate DTC (Ref. 30). In the past, cost information was not normally available to engineers. Apparently, this was done to avoid stifling design creativity. Now, however, some contractors are providing engineers detailed cost breakdown sheets to help them become aware of cost ramifications relating to design techniques. Management is encouraging engineers to pursue promising, but unusual, approaches to problems. To eliminate long delays caused by reviewing designs, engineers are being told, "Be sure you're right and then go ahead." Emphasizing flexibility, designers are told not to "fall in love" with their efforts. Nothing is immune to change. Morale within the manufacturing departments appears to be rising as their cost feedback helps drive designs. Production personnel are also being challenged to provide improvements.

Not everyone feels this way, however. There appears to be substantial fear and skepticism resulting from such freedom to trade away performance. Others with a "this too shall pass" attitude see DTC as just another spasmodic attempt by DOD to heal its incurable procurement ills (Ref. 30). Some contractors are afraid to submit what they feel are excellent designs that merit consideration, but still fall short of a threshold, for fear of being declared unresponsive. Others see

the DTC problem as attempting to maximize performance subject to a budgetary constraint. Cost is not being traded off (Ref. 31).

These mixed feelings and misunderstandings must be properly addressed and dealt with if DTC is to receive a fair test as a procurement strategy.

I. PROBLEMS AND CRITICISMS

The formal introduction of DTC upon DOD occurred in mid 1971. Since that time there has been much written describing difficulties associated with how DTC is being applied. Several of the criticisms described below have applied to prior procurement techniques as well as to DTC. These are ills seemingly related to DOD procurement as a whole. Other difficulties apply only to DTC as it is currently done.

1. Problems Related to Finance

Single-year funding procedures used by Congress have had an adverse impact upon weapons procurement (Ref. 19). Money is provided only on a yearly basis, with no guarantee of what the future holds. As a result, managers tend to look only at current program phases. Being ignorant of what future funding levels will be, program managers are not in a position to intelligently plan very far in advance. Such long range planning, if it does exist, is not done as carefully as it should be. Delayed appropriations may cause work stoppage. Contractors, however, continue to incur expenses, adding to weapons costs. Line item budgets greatly hamper the flexibility with which money may be spent. In an effort

to obtain approval for programs, optimistic cost estimates may be supplied by both contractors and the services. In many cases, R&D expenditures are cut back. Such actions often return and haunt a program through its entire life.

Contractor revenues are still related primarily to the costs they incur. Cutting back expenses, especially during R&D phases, may result in decreased revenues for the contractor. Thus, one may find a developer, who has cash flow difficulties, having incentives to increase costs.

Any money that is saved through prudent project management is not normally available for other uses. Such funds are thereby effectively lost to the service. This depresses motivation to pursue an active cost control program.

Programs involved in developmental work have a requirement for substantial management reserves. In many cases, however, such funding reserves are denied to management (Ref. 32). Contracts often make no provisions for reserves. Program managers may find contractual reserves denied, either because they were not authorized, or the money was removed for other uses. Thus, potential cost reduction ideas may not be suitably funded. Overall costs thereby become unnecessarily high.

2. Problems Related to Source Selection

Government selection of contractors is greatly limited by policy and statuatory requirements (Ref. 18). Legislation has explicitly favored U.S. firms, small businesses, minority enterprises, depressed areas, and other special interests.

Other laws affect safety standards, pay scales, pricing data, and discrimination policies of government contractors (Ref. 33). Such laws, while intended to serve some economic or social good, tend to restrict potential sources and eliminate competition.

Competition, if it does indeed exist, is largely eliminated once a program is commenced (Ref. 19). The situation then arises where the market consists of one buyer and one seller. Negotiations at this point tend to center about financial areas. It is generally felt that competition for a contract threatens a company with a loss of business, affecting its stability, and is, therefore, a far stronger stimulus than is the profit incentive. Although separate contracts must be written for each phase, the contractor who did the last development work holds a distinct competitive advantage. The situation that now arises begins to strongly resemble total package procurement. The problem of the "buy in" has thus yet to be solved.

3. Problems Related to Requirements

Although DTC has emphasized the use of performance specifications, there is still widespread usage of MIL SPECS and other detailed specifications (Ref. 32). These restrictions continue to hamper R&D efforts and restrain creativity. As a result, the beginning phases of development require many program changes. Change approvals, however, continue to entail much delay. This further hampers design iterations and increases costs.

Competitive selection criteria are not being adequately communicated to contractors (Ref. 32). Underlying statements of needs are not provided. Intelligent tradeoffs to meet these needs are thereby curtailed. Such information is especially critical during conceptual stages.

Proper drawing up of RFP's and goals requires inputs from the industrial world. Free exchange of information between contractors and DOD poses problems with respect to the protection of unique approaches and proprietary data. Conflicts are especially noteworthy in areas where the Government has helped to fund R&D efforts.

There has been a conflict in desires between the originality sought by DTC and the standardization and simplified logistics given by use of GFE. There is no guarantee that GFE is necessarily the best or cheapest available. Obviously, there is a tradeoff to be made in this area. Procudures for handling this problem do not seem to be clearly defined (Ref. 32).

The changed reporting requirements relating to DTC have had profound implications upon contractor accounting and management information systems (MIS). Most industrial accounting and management procedures have historically been geared to look back and justify past expenditures, rather than to look ahead and plan future activities (Ref. 19). Recent directives have dictated usage of the existing MIS as much as possible in tracking DTC. The forward-looking nature of this requirement, combined with the rearward-looking MIS poses yet another set of problems.

4. Problems Related to Project Management

Military project managers and their project teams are often selected long after the project itself has commenced (Ref. 19). The project team arrives on the scene to find most program parameters already firmly set. Proper handling of decisions and changes is most critical in the conceptual stages. At this time, however, there is no single person in charge of the project. Change procedures are ill defined and require massive documentation. Long turn-around times for ECP's drastically limit the amount of tradeoff analysis and the numbers of design iterations. This impacts adversely upon project optimization.

Project managers in the commercial world are given a great deal of authority to determine the course and scope of project development. This is not the case within DOD. High visibility to both press and Congress has resulted in extensive decision review and excessive paperwork demands. The lengthy review delays timely decisions. In addition, heavy paperwork and public affairs responsibilities detract measurably from the time available for actual management duties. Lengthy lines of communication within the DOD bureaucracy have led to conflicting policy interpretations and confusion. Such actions as may be directed by the project manager must pass via, and be approved by, contracting officers, who belong to a different bureaucracy with a different set of goals. This again contributes to more costly delays.

Rotation and tenure of program managers have posed a series of problems (Ref. 19). The manager, regardless of competence, rotates quickly in and out of his job before he can become familiar with it, or see the results of his efforts. The rotation schedule is arbitrary. The manager may leave or enter at a critical phase of the program. Thus, the man in change never really is aware of what is happening. He must deal with an entrenched bureaucracy that will be around long after he is gone. Project managers are often line officers having wide operational experience but little training applicable to the project environment. This inexperience, coupled with rapid rotation, has resulted in many restrictions, regulations, and other forms of management by document. The military structure, intended to preserve discipline and standardization, has been accused of stifling innovation, initiative, and risk taking. Emphasis appears to be upon accountability and control rather than efficiency and effectiveness.

5. Problems Related to Emphasis Level of Life Cycle Cost

DOD Directive 5000.1 envisioned DTC as being applied to LCC reduction. Practically speaking, however, UPC has received far more attention. LCC projections require far more time and experience to verify. Finally, DSARC has agreed to accept UPC goals as at least an interim solution.

Past experience has shown, however, that for many systems the visible support costs over a ten-year life span range from three to ten times the acquisition costs (Ref. 34).

It is in the best interests of the government to place far more emphasis upon LCC than it has done in the past. Data shortages have made LCC projections quite difficult to make. Lack of short term verification discourages LCC as a design parameter. Contractors in danger of overrunning costs will place special emphasis upon UPC to escape criticism or threats of program termination. Finally, a detailed usage and support plan for a piece of military equipment having a lifetime of many years is very difficult to define. The many political, military, and economic contingencies possibly facing a weapon system over a period of ten to twenty years cannot be enumerated. Without a preplanned usage agreement, LCC projections are meaningless. There appears to be little hope of a resolution to this problem in the foreseeable future.

IV. CASE STUDIES

DOD Directive 5000.1 imposes the Design-to-Cost requirement upon all major weapons systems currently under development. Most systems reaching operational status at this time had the Design-to-Cost requirements forced upon them as a retrofit, after initial R&D contracts were awarded. As a result of this retrofitting, a true picture of the effectiveness of DTC is difficult to measure. The programs which included DTC from their conception have not yet become operational. For these reasons, a comprehensive evaluation of the effects of DTC is not currently attainable. Trends have been established, however, which may indicate the value of DTC and potential problem areas and limitations.

The following case studies present the various techniques in which Design-to-Cost has been implemented in recent DOD aerospace programs. This selection, while not exhaustive, does provide a sample of recent attempts to apply the requirements of DOD Directive 5000.1. Cases presented include:

Air Force Close Air Support Aircraft
Army Advanced Attack Helicopter
Utility Tactical Transport Aircraft System
SAM-D Missile
Subsonic Cruise Armed Decoy
Lightweight Fighter
Navy Lightweight Fighter
NWC, China Lake Projects

The cases presented vary considerably in scope and detail. This is largely due to the relative availability of data. These limitations facing the authors stemmed from

geographic constraints, data sensitivity, contract availability, security classification, or political considerations. Furthermore, several redundant aspects common to more than one program are not continually duplicated.

A. AIR FORCE CLOSE AIR SUPPORT AIRCRAFT (A-10)

1. Background

The Air Force began development of the requirements for a close air support (CAS) aircraft in 1966. To accomplish this, six contractors were funded between 1966 and 1970 to develop Concept Formulation Packages (CFP). These CFPs were intended to define aircraft performance parameters to best satisfy the CAS mission. Using the results of parametric cost analysis studies, a unit recurring flyaway cost of $1.2 million (FY '70 dollars) was established. The program entailed the procurement of 600 aircraft to be purchased at a rate of twenty aircraft per month (Ref. 35). The cost estimate was based on the assumption the aircraft would use a turboprop propulsion system rather than a turbojet or turbofan. This was due to the non-availability of a small turbojet or turbofan engine in the 9,000 pound thrust class, during the formulation study period. Subsequently, a turbojet in this thrust class was developed. The Air Force increased the cost estimate to $1.4 million to encourage contractors to incorporate this new engine. The turbofan is slightly more expensive than the other types; however, it has better fuel economy, reliability, and maintainability. The cost target was again increased to $1.5 million per aircraft to

include non-recurring costs such as initial tooling and work set up.

In the spring of 1970, the Air Force received authority to prepare a RFP for the CAS weapons system. At this time the project was designated the AX program. Competitive prototype phase (CPP) solicitations were requested from eleven aircraft producers. After four months devoted to source selection, then Secretary of the Air Force Seamans, in December 1970, authorized CPP firm fixed price contracts to be awarded for the development of two prototype aircraft each from Northrop Corporation for the A-9 and Fairchild Industries, Fairchild Republic Division for the A-10. The contract price was the same as requested in contractor proposals. Fairchild asked for and received about $12.0 million more than Northrop because they intended to design and manufacture from the start a prototype that was in essence a pre-production aircraft (Ref. 36). Two years later, in January 1973, following the competitive Air Force flight evaluation of the full scale development and production proposals, Fairchild Republic was selected to develop the A-10 for the CAS role. There was considerable Congressional debate as to the legitimacy of the award. Northrop's entry was potentially less expensive ($50,000 - $100,000 per aircraft), mainly because of less costly Avco Lycoming engines. However, Fairchild's prototyping was a key element in the Air Force selection of the A-10 (Ref. 37). Fairchild Republic was awarded a cost plus incentive fee (CPIF) contract

to build ten pre-production aircraft on a negotiated schedule. The incentive was for cost reduction alone, not for increasing performance. Congress cut the order to six pre-production aircraft in 1974 (Ref. 38). The Air Force negotiated a fixed price option for two aircraft buys. The first option was for between 22 and 39 aircraft. The second was for between 11 and 33. At this time the Air Force has elected to receive 26 from the first and 22 from the second (Ref. 39). The first production aircraft delivery date has been set for December 1975.

2. Design-to-Cost Contract Features

There are four primary subsystems of the A-10. Of these, three were contracted for by the A-10 Systems Program Office (SPO) at Wright-Patterson Air Force Base, Ohio. These were (Ref. 40):

(1) Airframe and total system integration with Fairchild Republic Division, Fairchild Industries, Farmingdale, New York (prime contractor)

(2) TF-34-100 Engines with Aircraft Engine Group, General Electric Company, Lynn, Massachusetts

(3) GAU-8/A 33mm Gun with Armament Department, General Electric Company

The fourth subsystem, the avionics group, is not being procured through the A-10 SPO. This is being furnished as GFE. Each of the contracts prepared at the A-10 SPO includes Design-to-Cost clauses as a special feature of a cost type contract. Since the three contracts were similar in nature, only the prime contract will be expounded upon. The main Design-to-Cost clause reads in part:

"DESIGN TO UNIT FLY-AWAY COST

a) Unit production fly-away costs are defined as the sum of all recurring and non-recurring costs (excluding all RDT&E costs) necessary to produce a complete aircraft, including the applicable portion of system engineering and program management. This definition excludes all costs associated with the production of AGE (aircraft ground support equipment), Training, Data, Initial Spares and the applicable portion of system engineering and program management . . .

b) A prime objective during Full-Scale Development is to design to a cumulative average unit production fly-away cost of $1.5 million expressed in FY 1970 dollars for a total of 600 aircraft . . . to attain a maximum rate of 20 aircraft per month." (Ref. 41).

Engineering Change Orders (ECO) are included in both the recurring and the non-recurring costs. The contractor is held responsible to control and track his portions of the costs and to report any cost changes over $3,000 on the Monthly Cost Performance Report in both current and FY '70 dollars. He is also to report any actions or tradeoffs he proposes to take to bring the costs back within the limit. The breakdown for the recurring costs is shown in Table III (from Ref. 42).

It is apparent from the contract that the unit production fly-away costs include only a portion of the total life cycle costs. The major exclusions, besides RDT&E and the others listed above, are operation and maintenance costs. There are several significant points which should be noted.

(1) A <u>$1.5 million target cost</u> is specified to give the contractor a definite cost figure for which to design and evaluate tradeoffs.

(2) The uncertainty of inflation will not affect the cost goal because it is expressed in <u>constant dollars</u>. This is important since the last aircraft is scheduled for delivery in early 1978 (Ref. 43).

(3) A design goal of 600 aircraft is established so that production costs and the learning curve savings could be calculated and averaged out.

(4) The design production rate is specified. This allows for the development of an economical production system geared to this rate. Any change either to increase or decrease the rate would affect the cost.

(5) Including the costs of ECO in the $1.5 million limit insures that the contractor maintain a reserve for this purpose.

There are also a number of other special clauses in the contracts. These clauses identify the:

(1) limitation of government obligation
(2) government options
(3) life cycle cost responsibilities
(4) award fee provisions
(5) changing and allocation of costs
(6) system integration responsibilities and demonstration milestones.

TABLE III

A-10 FLYAWAY AVERAGE UNIT COST

	Dollars (1970 Thousands)		Percent	
Air Vehicle				
Airframe (CFE)........	805.1		57.4	
Labor		354.2		25.3
Raw Material........		66.1		4.7
Equipment...........		221.8		15.8
Subcontract.........		101.5		7.2
Avionics............		61.5		4.4
GFAE.................	598.7		42.6	
Other GFAE..........		45.5		3.2
Avionics............		38.2		2.7
Gun.................		85.0		6.1
Engine..............		430.0		30.6
TOTAL......	1403.8		100.0	

600 Aircraft: Units No. 11 through 610

The costs applicable to the Design-to-Cost goals must be separately collected, recorded, and reported. The Total System Integration Responsibility clause makes Fairchild responsible to insure the entire system cost remains within the $1.5 million cost goal. This means Fairchild must monitor subcontractors' costs as well as its own. However, unlike the Total System Performance Responsibility clause used in other major weapon system contracts, Fairchild is required to accept and integrate all GFE, but only to insure that the GFE performs to its specifications rather than to total system specifications. The life cycle cost clause insures that tradeoffs in performance will be weighed against their impact on life cycle costs. Changes in design will be made only if they reduce both unit cost and life cycle costs. Failure on the part of Fairchild to meet the Design-to-Cost goal in any of the areas discussed could result in possible contract termination (Ref. 43).

3. Design Tradeoffs

The RFP for the CPP was carefully prepared to eliminate all unnecessary MIL SPEC and MIL STD requirements. The Design-to-Cost objective was the only requirement stated in the initial RFP. Performance was stated in terms of goals in the areas of responsiveness, lethality, survivability, and simplicity in order to accomplish the CAS mission (Ref. 44). These changes, coupled with the new concept of Design-to-Cost in military procurement, left uncertainty as to the importance of the cost target in the minds of the bidding contractors.

However, after Air Force briefings these contractors became aware that maximum possible design freedom was left to the company and that the design had to be within the cost limit (Ref. 23). Fairchild found it necessary to insist that subcontractors adopt the same cost conscious attitude and make tradeoff studies of their own to provide lower cost options. In order to insure the lowest possible production costs, Fairchild organized a design team which incorporated all levels of engineering and manufacturing. The team used a design approach for the prototype aircraft which would eliminate as much risk in the production follow-on as possible. This included designing as many components as possible to the production configuration. Tradeoff studies were also conducted to determine optimum design in the following areas (Ref. 42):

1. load factor
2. survivability
3. ammunition capacity
4. fuel capacity
5. external payload
6. take off and landing distance
7. landing gear flotation
8. engine thrust level.

As a result of this concept, the following low cost design and manufacturing techniques were incorporated within the A-10 (Ref. 45):

(1) Engine: In order to reduce the cost of the TF 34 engine, unneeded features were discarded such as the Navy required fuel heaters for JP-5 fuel. Many titanium parts were replaced with steel. These resulted in a cost savings of $45,000 per engine.

(2) Airframe design: Many features were designed into the airframe to aid in cost reductions. Among these were:

a. simple external lines
b. constant cross section fuselage segment
c. single curvature skins
d. simple structural elements
   --one-third of the wing span is constant cross section with straight spars and ribs
   --horizontal stabilizer has constant cross section (18 of 20 ribs are identical)
e. greater than normal protuberance tolerance.

(3) Landing gear: Open landing gear pods arrangement allows both simplicity and weight savings.

(4) Engine location: The high externally mounted engines result in a simpler fuselage design, permit easy access for service and maintenance, and minimize the danger of foreign object ingestion.

(5) Wing selection: An airfoil with high lift characteristics at low speeds was selected in order to reduce the necessary wing area and resulted in a cost savings of about $50,000 per aircraft.

(6) Interchangeable parts: The following major assemblies can be used on either side of the aircraft:

a. built-up engine
b. vertical tail
c. elevators
d. inboard flaps
e. pylons
f. nacelle inlets and aft section
g. main landing gear
h. stabilizer ribs.

This interchangeability allows for a significant reduction in production costs and will permit the Air Force to minimize its spare parts inventory.

Additional production cost savings resulted fron constructing the prototype aircraft using the same methods as would be used for the production aircraft. By doing this, Fairchild used the lessons learned during the prototype development to save considerable time and money and to avoid a great deal of risk resulting from production method changes. Through its experience, Fairchild determined which subassemblies

to have built up. It could pre-position parts, hardware, equipment, and men to form a "speed-line," helping to accelerate aircraft production. The A-10 program director, Col. James Hildebrandt added

> "There is no question in my mind that the (Fairchild) A-10 would cost more than $30 million more (in future development) if it hadn't had competition from the (Northrup) A-9 (on which the Air Force spent $29 million). I am quite sure Fairchild would have gone more for optimizing performance if it hadn't had competition to hold the cost down." (Ref. 46).

This dramatically shows the influence of competition in holding down costs.

The A-10 program has been a success thus far because a lot of people have made the right decisions at the right times. Achievable goals were established early in the program conception phase. The aircraft requirements were realistically set. Contractors, managers, and engineers were kept informed. Through necessary tradeoffs, acceptable performance was provided within a price the Government can afford to pay.

B. ARMY ADVANCED ATTACK HELICOPTER

The Army authorized development of the advanced attack helicopter (AAH) in 1972 after comprehensive studies verifying its necessity. The primary mission to be performed by the aircraft is to supply close air fire support for ground forces. The helicopter is intended to be a high performance weapon system to balance the capabilities of lower performance AH-1 series attack helicopters presently in the Army inventory.

The performance requirements for the AAH were developed through comprehensive analysis of anticipated threat environments and after careful evaluation of the capabilities of existing and anticipated weapon systems. A study was conducted by the Army to reevaluate and update former requirements for the Cheyenne, Advanced Aerial Fire Support System, which was becoming too expensive for the mission and had come under attack by Congress. The result of the study was a recommendation for the AAH. The Material Need document presented the requirements for the desired performance characteristics, airframe and subsystem configurations, armament capabilities and payload. These items were derived on a cost and mission effectiveness basis and were expressed in terms of performance bands. The lower level of the band represented the minimum acceptable performance. The desired performance corresponded to the high end of the band. The cost to achieve the upper level of performance was estimated to be only 15% less than the unit fly-away cost of the Cheyenne system, at that time about $2.7 million per copy (Ref. 47). The Army and DSARC agreed to design to a goal of $1.4 to $1.6 million unit recurring fly-away costs. The major design criteria of the AAH include: (Refs. 47, 48)

--maximum survivability, including reduced radar cross section, armor protection, self-sealing fuel tanks, and total structural resistance to small-arms fire

--maneuverability, including exceptional lateral and vertical performance, side-slip turning, and tight turning at high speeds

--all weather flight capability to include "nap-of-the-earth" terrain following allowing popping up to acquire targets and deliver weapons.

The specifications for the AAH RFP were carefully prepared in order to verify that all requirements were valid and necessary to achieve both the design objective and the operational requirements. All unnecessary requirements were eliminated so that the bidding contractors could have maximum freedom to use their initiatives to design and develop proposals most advantageous to the Army from a cost, performance, and schedule point of view. In addition, the Army asked the bidders "to place major emphasis on cost reduction through critical examination of performance characteristics, improving producibility and innovative production techniques (and) to exercise their judgement and make tradeoffs to meet the design-to-cost goal" (Ref. 49).

The RFP was released in November 1972 and was answered by five aircraft manufacturers in February 1973. These included:

--Bell Helicopter, which had a contract for improved Huey Cobras.

--Lockheed-California Co., which had done some prior development on the AH-56 Cheyenne.

--Boeing Vertol Co., which is working on the Army UTTAS.

--Sikorsky Aircraft Div., United Aircraft Corp., which is also working on UTTAS and the Blackhawk helicopter.

--Hughes Helicopters.

After comprehensive evaluation of these proposals, the Army awarded cost plus incentive fee (CPIF) contracts with an award fee provision for competitive prototypes to Bell and Hughes in June 1973. A provision was included not to proceed until after revalidation (within 30 days).

This time was used for reviewing the projected unit costs by the Army and OSD Cost Analysis Improvement Group (CAIG), and to insure the consistence of the DTC goal with respect to other cost reporting procedures. The contractors were to use this time to identify additional cost reduction possibilities.

The portion of the contract (Ref. 50) addressing DTC states:

> "The primary objective of this contract is to develop a cost effective, reliable and easily maintained advanced attack helicopter system . . . with a unit recurring average flyaway cost of $1,349,093[1] or less, including $282,000[1] design to cost for Associate Contractor equipment. Emphasis is to be placed on life cycle cost reduction through producibility of operational design features and maintainability and reliability . . .
>
> "The Contractor's System Specification describes an aircraft which the contractor expects can be produced for the cost established above (FY 1972 constant dollars), based upon the quantity and schedule (confidential). It is limited to recurring costs . . . which include the recurring costs of <u>Contractor furnished subsystems and the Government furnished material</u> (Emphasis added)."

The award fee is an incentive for achievement of the design to unit production cost. However, the award fee will be determined <u>unilaterally</u> by the Government and a maximum amount is stated in the contract. A Sikorsky Aircraft Division vice president expressed reservations about the way of rewarding the contract (Ref. 51).

Another interesting point of this contract is the fact that the means for determining fee adjustment was explicitly stated.

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[1] For Hughes Helicopter, Hughes Aircraft Company.

"The implicit Price Deflator for the total Gross National Product (index base 1958 -- 100) published by the Department of Commerce, Bureau of Economic Analysis as reported periodically in the United States Department of Commerce publication entitled 'Business Conditions Digest' will be used to adjust current year dollars to average constant FY 1972 dollars."

The AAH is, however, experiencing cost increases in excess of funding. As a result, the program is being stretched. This is expected to increase unit production costs in future years (Ref. 52). It was expected that a competitive prototype flyoff will be performed starting in March 1975, and a contract for engineering development will be awarded to the winner in June 1976. These dates may slide as a result of above mentioned difficulties.

C. UTILITY TACTICAL TRANSPORT AIRCRAFT SYSTEM

The Utility Tactical Transport Aircraft System (UTTAS) will be the Army's replacement for the Bell UH-1 Huey troop carrying helicopter. UTTAS is to be faster, safer, more versatile and less expensive than the Huey. It is designed to be air transportable to any place in the world and readied for flight within minutes after unloading (Ref. 53).

The RFP for the UTTAS was preceded by an intensive Army study to determine the exact requirements to be included in the specification. The study by the Army Combat Developments Command (Ref. 54) covered all aspects of UTTAS project, including costs, tradeoffs, and utilization. The release of the RFP, however, aroused some criticism from Congress. The Senate Armed Services Research and Development Subcommittee questioned the following aspects of the request:

1. the use of prototyping,
2. the length of the RFP,
3. the reliability goal of 0.986,
4. the requirement for the development of six prototypes from each contractor,
5. the cost of engine development, and
6. the need for the UTTAS.

These issues were answered by Brig. Gen. William J. Maddox, Director of Army's Aviation (Ref. 55), bringing the Army's views out into the open for criticism and rebuttal.

Source selection for the competitive prototype phase of development was announced 31 August 1972. Vertol Division of Boeing Co. of Philadelphia and Sikorsky Aircraft Division of United Aircraft Corp. of Stratford, Conn. were awarded contracts for the development of the YUH-61 and the YUH-60, respectively for a competitive flyoff. This flyoff is scheduled to take place in early 1976. The only other contractor competing for the project was Textron's Bell Helicopter Division, which also built the Huey. Its proposal was not completely responsive since it tried to incorporate all it knew about utility helicopters into its design. Industry sources said that Sikorsky's UTTAS was superbly engineered and was designed right to the Army's DTC target (Ref. 56).

The UTTAS is the first Army helicopter project undertaken with the implementation of Design-to-Cost in the contract (Ref. 51). The DTC objective of the RFP (Ref. 57) states:

> "An objective of this contract is the successful development of a Utility Tactical Transport Aircraft System that can be produced at the lowest possible production and life cycle cost. Therefore, in recognition of this objective, the Contractor shall place maximum emphasis on cost reduction through improved producibility, maintainability, reliability and operational design features. It is agreed and established that the

UTTAS shall be capable of being produced at an average recurring airframe cost of $600,000 or less (constant FY 1972 dollars) based upon the total production quantities shown in Attachment 15 (confidential) of this contract."

The contract further states which costs will be included in this airframe cost objective:

"The airframe recurring cost includes recurring engineering direct labor and applicable engineering overhead, manufacturing overhead, general and administrative overhead, material and profit on recurring costs only, associated equipment such as engines, avionics and weapons. Nonrecurring costs such as tooling, nonrecurring engineering, and total costs of kits, GSE, GFE and data are excluded"(emphasis added).

The Implicit Price Deflator is used to correct from FY '72 dollars to current dollars, as in the AAH contract. A formula is also provided in the contract to provide for computation of an incentive or penalty fee relative to the design-to-cost objective. The UTTAS, being one of the first DTC procurements, is not as tightly constrained by the cost goals as subsequent projects, including the AAH (Ref. 52). A decrease in funding for FY '75 will slow the project another couple of months. The UTTAS has already been extended two years as a result of changes in the Army procurement plans. R&D through FY 1974 has cost the Army $187.2 million. Total program costs for 1,107 helicopters are estimated at $2.675 billion (Ref. 52).

Both prime contractors for the airframe have expressed confidence in the DTC cost goals. Cost control for Sikorsky Aircraft involves two major activities (Ref. 58):

1) The cost/schedule planning, tracking, and control of all program operations, and

2) the targeting, tracking, and control of product cost generated by program operations.

The application of the DTC concept involves four interrelated activities including:

Design-to-Cost Target. These provide a positive control on the final product costs generated by the design phase.

Tool-to-Cost Targets. The designers are given the planned extent and type of tooling as factors to use in tradeoff studies to determine alternative design approaches. In the production phase, these goals become the tooling cost targets to be met by the manufacturing department.

Purchase-to-Cost Targets. These goals influence the selection of purchased parts and proprietary items in the design phase. In the production phase, they help control costs by influencing the selection of the source of production parts and equipment.

Manufacture-to-Cost Targets. These are cost estimates issued to the manufacturing department and monitored by Silorsky's tracking system. Heavy emphasis was placed upon the design phase, where considerable effort was expended by designers to optimize their plans from a cost standpoint.

Boeing Vertol Company has taken a different approach to the DTC problems (Ref. 59). Their plan "involves limiting requirements to mission essentials, controlling sophistication, identifying high cost designs, increasing standardization, incorporating design to cost as a discipline consistent with dynamics and stress, and providing the designer with guideline bogeys and tools by which he can attain them."

One of the major areas of emphasis is the reduction of parts to perform a function. Each system was given a parts count bogey and the designer tried to design a system which uses fewer parts than the bogey. Through cost estimating relationships, Boeing Vertol has shown that reducing the number of parts leads to reducing costs. In addition to

parts reduction, the designer was encouraged to use automatic riveting where possible since studies have shown that manual riveting costs about five to six times more than automatic riveting.

Through the use of increased emphasis on cost control throughout the program, both contractors are trying to meet the Design-to Cost goals.

D. SAM-D MISSILE

The Army's SAM-D, surface-to-air missile system, is designed to provide a mobile air defense for use with large Army units. The SAM-D system is scheduled to replace both the Raytheon M1M-23A Hawk missile and Western Electric M1M-14B Nike Hercules in the 1980's (Ref. 60). The system is composed of four major subsystems: the missile, radar group, weapon control group, and the launcher group. These components are assembled into a "fire section" consisting of several weapon launchers, each with four missiles, a radar unit, and a control unit which houses the computer. The launchers, remotely located from the radar and control shelter, operate over a radio data link. Six SAM-D fire sections comprise a battalion which may be operated by as few as 33 men (Ref. 61). All components are mounted on standard Army vehicles. A battalion can be transported by either C-141 or the Army's heavy lift helicopter.

In March 1972, following five years of advanced development, Raytheon Company was awarded the full-scale engineering development contract (Ref. 62). This contract extends through December 1977 and has a total value of $564.8 million (Ref. 63).

The total RTD&E costs are estimated at $1.1 billion. An additional $91 million is in management reserve. Estimated total costs for the complete program are $4.5 billion. The development contract with Raytheon is cost plus incentive fee with Design-to-Cost goals for each of the subsystems. Table IV shows the cost goals, number of units to be produced, and Raytheon's expectations of meeting each goal.

TABLE IV

RAYTHEON DESIGN-TO-COST GOALS
(Source: Ref. 61)

Item	Cost Goal	No. Units	Contractor's Expectations
Radar Unit	$2.8 million	125	below goal
Launchers	$250,000	625	close
Control Unit	$887,000	125	below goal
Missile	$90,000	6,250	hardest to meet, close

The cost goals are based on established hardware configurations using 1972 constant dollars. Production schedules and cost relationships were negotiated. The unit production price includes

> "all costs normally included in the contractor's hardware production contracts such as all labor, including fabrication, assembly, test and inspection, manufacturing, engineering, and production control, all material, including purchased parts, raw materials, and subcontracts; all burdens including labor and material overhead, maintenance and modification of special tooling and test equipment and profit and fee" (Ref. 43).

Management of effort toward achieving the production unit price objective comprises one criterion in evaluating Raytheon's performance toward an award fee, not to exceed $5,068,857.

If Raytheon is selected to produce the SAM-D, an additional reward/penalty provision will be included. There will be an increase of 15% in earned fees if the final cost is less than 10% below target, and a decrease in fees of 25% for costs greater than 10% above target. There will be no fee adjustment for costs within 10% of target. There is, however, a 65/35 share ratio on all costs or savings within 10% of target. The techniques used by Martin Marietta, the missile development subcontractor, to reduce cost are discussed in reference 26.

There is no competing contractor for the SAM-D system, consequently there will be no fly-off or other system with which to compare the Raytheon proposal. The cost reducing incentive which competition brings is also missing. The SAM-D has been attacked repeatedly by Senator Bayh (D-Ind), questioning its necessity. In July 1973, his amendment to the Defense Authorization Bill to delete all SAM-D funds was narrowly defeated. In January 1974, the Senator succeeded in requiring that a new cost-effectiveness study be conducted. The analysis is being performed by OSD and the Army, with the consultation of Congressional and GAO staffs (Ref. 53). The Senator has stated that

> "the SAM-D program exhibits many of the characteristics identified with questionable weapon systems in the past. They include changing capability requirements, persisting technical uncertainties, unrealistic threat assessment, postponed testing, incomplete cost-effectiveness analysis, escalated costs for fewer units and inadequate justification for the quantities to be procured." (Ref. 62).

In January 1974, then Deputy Defense Secretary Clement reoriented the SAM-D program to SAM-D2 and shifted it from engineering development back into advanced development. The Army issued a "stop work" order February 4, 1974, which suspended hardware and engineering activities, with exception of guidance test flights. In its program reorientation, the Army is studying (Ref. 63):

1. tradeoffs to enhance low-altitude capability,
2. fire section hardware cost goals,
3. design for operation against a less intense electronic countermeasure environment (a key cost reducer),
4. increasing system mobility,
5. use in the continental air defense mission as a secondary priority,
6. minimizing costs until the guidance system has been successfully demonstrated.

The Defense Department reduced FY '75 funding by $54.7 million to $111.2 million. Congress is considering reducing the funding another $11.2 million because of missile guidance problems.

In October 1974, the Army began a test program to permit a production decision June 1975, on the less costly SAM-D2 version of the missile. It would reduce costs of the system by including modifications to:

--eliminate one transmitter chain
--remove four sidelobe cancelers
--reduce memory
--eliminate one display console
--provide for alternate surveillance long-range waveforms

As of November 1974, the Army is seeking to minimize costs of the program while awaiting tests of the guidance system. If these tests prove successful, the Army wants to be able to make an efficient transition to full scale development (Ref. 63).

As a hedge against failure, the Army is planning to award three additional contracts in January 1975, each for $1 million, for development of a complementary guidance system. Expected contractors are General Dynamics, Hughes, and Martin Marietta (Ref. 64).

E. SUBSONIC CRUISE ARMED DECOY

The Subsonic Cruise Armed Decoy (SCAD) is an Air Force weapon system which was retrofitted with design-to-cost goals after the full scale development contracts had been awarded. The program was subsequently halted with one contract terminated, "pending further study because of rising costs and continuous debate over its required capabilities" (Ref. 65).

The SCAD is an air-launched guided missile, designed to be carried aboard the B-52. It would be launched prior to aircraft penetration of enemy early warning defenses. SCAD, by simulating the mission profile of the B-52, would draw fire toward itself and away from the manned bomber.

The Air Force divided the program into five separate subsections for management and award of contracts, after DOD authorization in mid-1972. The first SCAD contracts were let in June 1972, when Williams Research Corporation and Teledyne CAE were selected to develop small, efficient turbofan engines to power the SCAD. Teledyne received $4.38 million and Williams got $3 million to conduct an eight-month demonstration phase for their respective engine designs.

The principal guidance subsystem competitors were Northrop, Singer Kearfott, Bendix, Delco Division of General Motors, Litton Industries, and Boeing Company.

The airframe competitors were Boeing and Lockheed Missile and Space Company. The decoy subsystem, which included noise jamming transmitters, set-on receivers, and target repeaters, was bid on by Hallicrafters, Philco-Ford, RCA Corporation, Sanders Associates, and a team of GTE Sylvania and Raytheon. The subsequent contracts were awareded by July 1972, to:

--Boeing Company for the airframe and air vehicle,

--Philco-Ford for the decoy subsystem,

--Litton Systems, Inc. for the guidance and control.

The SCAD System program office was organized similar to other Air Force Aeronautical Systems Division (ASD) SPO's, except for three distinct characteristics. First, it retained in-house, a major portion of the program management, including systems integration. There was no prime contractor responsible for the integration of the components. Second, a systems analysis office was responsible for monitoring any evolving threat in the Soviet defensive network to determine if capability changes were required for the SCAD. The office was to work closely with the Strategic Air Command and the ASD's intelligence-gathering Foreign Technology Division. Third, the procurement office was assigned responsibility to monitor procurement schedules, costs, and performance, if production is authorized in the future (Ref. 66).

The original RFP stated the Air Force objective as the accomplishment of the program development at a minimum cost.

Development contracts were of a cost incentive type. Design-to-Cost, however, was not part of the original contracts. In October 1972, the contractors were asked to evaluate the additional cost of contracting for the design to cost. In November 1972, the contractors reported back to the SPO that it would cost an additional $5 million to implement DTC. This price was considered unreasonable. The SPO negotiated with each contractor to implement no-cost supplemental agreements. These were to provide (Ref. 23):

1. the recognition of a DTC goal for <u>recurring production costs</u>,
2. a monthly review of the cost goal at Segment Status Review meetings,
3. a detailed analysis of the goal at key program milestones, and
4. an amendment to the statement of work requiring future ECP's to include the net change in the cost goal which would result.

By January 1973, all contracts were modified; however, no incentives or penalties were incorporated to enforce adherence to DTC goals. Contract modifications differed slightly. Boeing refused to accept the ECP provision. Litton and Teledyne agreed to indicate the impact of an ECP only if the DTC goal changed 10% or more. Litton later changed this to 2%. As an example of the negotiated clauses, the January 1973 Litton supplemental agreement states in part (Ref. 67):

> The contractor hereby agrees that the Design-to-Cost goal for the SCAD Navigation/Guidance segment is $45,100 in then year dollars based on a total of 1500 units based on a delivery rate of two (2) units per working day. The Design-to-Cost goal includes all recurring costs associated with the unit production of the SCAD Navigation/Guidance segment, including direct material, material overhead, direct labor, labor overhead and G&A and excluding profit and Litton's budgetary estimate for

ECO and Project Management sustaining costs; and the aforementioned goal is based upon prior delivery of thirty-five (35) RDT&E Navigation/Guidance segments with initiation of production delivery immediately thereafter. The Design-to-Cost goal shall be addressed at each Segment Status Review (SSR) and reviewed if variance of approximately 10% in the Design-to-Cost goal is projected. The Design-to-Cost goal shall be reviewed and analyzed within 30 days after Critical Design Review, within 30 days after FCA/PCA and within 30 days after the Completion of Qualification Testing."

It is worth noting that the cost goal agreed to in this, a second modification, is $5,000 below that of the initial modification in 1972.

Although the attempt to implement DTC into the SCAD program followed the award of development contracts, the SPO was able to introduce cost goals and a means of reviewing those goals at no additional cost. Whether introduction at this time was too late or whether the costs were already too fixed is open to question. Without the existence of either an award or incentive fee, there was no economic stimulus to reduce cost. In addition, there were no competitive pressures toward cost reduction. Threat of contract termination provided the only incentive for contractors to consider costs.

In July 1973, DOD ordered the Air Force to halt full engineering development of SCAD. The Air Force issued a termination notice to Boeing Company on its contracts for modification of the G and H models of its B-52 bombers which were to carry the SCAD. The Air Force also issued a "stop work" notice on the Boeing airframe contract. Williams Research Corp. was instructed to suspend further development work on the engine. Philco-Ford Corp. was ordered to stop development of the decoy electronics package (Ref. 65).

In spite of the earlier contractual difficulties, the Air Force is negotiating with Boeing for design, construction and test of an air-launched cruise missile (ALCM), similar to the SCAD. The engine, the same as for the SCAD, will be supplied by Williams Research Corp. The Air Force intends to procure competitively the missile navigation/guidance subsystem (Ref. 68).

F. LIGHTWEIGHT FIGHTER

In April 1972, Northrop and General Dynamics were selected to design and build prototype lightweight fighters (LWF) for the United States Air Force. Each company was to build two aircraft. The fighter is to fit into the "high-low" mix concept. The McDonnell Douglas F-15 fighter ($15 million per copy) is to provide the high cost, sophisticated system with advanced long-range aircraft and missile capabilities. The LWF is to provide low-cost ($3.0 FY '72 dollars per unit) air superiority for handling a large portion of the close-in threat after initial encounters (Ref. 67).

The Air Force followed the broad guidelines laid down by former Deputy Defense Secretary David Packard when the Air Force Aeronautical Systems Division (ASD) prepared the RFP and evaluated the proposals. The project was handled by a newly formed, tightly-manned Prototype Programs Office (PPO). This office was established only eight months before the LPW contracts were awarded. Only 23 persons were assigned to it. Most statements of work issued by the PPO were limited to 25-30 pages. These included broad performance goals and

stressed the need for technology. Design-to-Cost and other dollar constraints were explicitly conveyed to prospective developers. Contractor proposals were also expected to be brief. About 50 pages were allowed for the technical portion and 10 pages for the management section. There were no restrictions on the cost proposal. In the case of the LWF, proposals were received at ASD on February 18, 1972, where preliminary evaluations were made. The PPO received the proposals on March 13, 1972. The winners were selected in April (Ref. 68). In evaluating these proposals, the PPO did not rate them on a scoring system basis as such. Each proposal was assessed individually, identifying strengths and weaknesses in the designs, based on computer studies.

The contracts were awarded on a cost-type basis with a maximum obligation. The General Dynamics contract was for $37.9 million. Northrop's contract was for approximately $39 million. There was no promise that the Air Force or any other U.S. service would order either design into production. The aircraft were not to be evaluated against each other in a flyoff. Instead, they were to be evaluated separately by contractor and Air Force pilots (Ref. 69). The DTG goal is $3 million in FY '72 dollars, to be produced at a rate of 100 per year for three years (Ref. 70). That cost includes airframe, engine, and avionics.

1. General Dynamics YF-16

The YF-16 is a single-seat, single engine aircraft optimized for air-to-air combat by providing good visibility,

high maneuverability, fast acceleration, and improved radius of action (Ref. 71). The program personnel designed the aircraft as an operational vehicle from the beginning. The only departures were made to meet cost and schedule requirements for building the prototypes. The design goal was to produce a low cost aircraft with a high degree of combat maneuverability. This was to be achieved by building the smallest, lightest vehicle possible and integrating advanced technologies that promised low risk (Ref. 72).

A number of technological advances and design tradeoffs were made in order to meet the DTC goals. These include:

(1) engine selection
(2) component standardization
(3) aerodynamics innovations including:
--leading edge maneuvering flaps
--bending wing-body
--forebody wing strakes
--fly-by-wire control system
(4) design simplification
(5) parts reduction and duplication

The Pratt & Whitney F100-PW-100 turbofan engine was chosen for the YF-16 because it is used in the F-15 and its logistic support would already be available in the Air Force inventory. The improved fuel consumption of a turbofan over a turbojet was desirable to help provide the required flight radius. The decision to use a single engine to help minimize the size of the aircraft saved approximately 15% in the design gross weight, compared with the use of two engines. There was also an additional dollar savings due to increased simplicity and need for fewer controls and instruments. The cost of the engine has been reduced by substitution of sheet

and stringer construction in the external ducts in lieu of honeycomb material. This decreased the cost about $7,500 per engine. A simplified augmentor nozzle actuator system is saving about $14,000 per engine. The engine changes are not unique to the YF-16. These changes have come from the F-15 program and have benefited both aircraft.

The use of a considerable number standard components already in Air Force supply system is expected to save time and cost. The YF-16 engineers identified 254 components in the airplane that are identical with those used in other aircraft. Only 20% of the components utilized in the two prototypes were new (Ref. 73).

Advanced aerodynamic techniques were used in the YF-16, primarily to meet the design goal of producing a highly maneuverable fighter. Many of the tradeoffs have resulted in cost savings. The use of leading edge maneuvering flaps, incorporated to provide a better lift-to-drag ratio in high-g-turns, allowed the use of a smaller, lighter wing. Wing-body bending provided increased lift from the fuselage, especially at high angles of attack. As a result, fuselage volume was improved by approximately 9%. Fuselage length was shortened by approximately five feet as compared to conventional designs. An additional weight savings of over 550 pounds has resulted. Forebody wing strakes, used to improve lift and stability, also made possible a smaller wing. The fly-by-wire control system eliminated the need for hydraulic lines and control surface actuators throughout the aircraft.

Although the system is more expensive than conventional hydraulic controls, the savings in size and weight more than make up for the cost (Ref. 74).

Designers were concerned with building in economic manufacturing features as well as advanced technology. A special standards book was developed for the engineers to aid in parts selection. To keep down manufacturing costs, formed sheet metal was utilized where possible, instead of more expensive bonded structures. Machined parts were designed to be worked on one side only, in most cases. These simplified parts may be constructed by use of routers instead of costly milling machines.

Aircraft subassemblies were designed for interchangeable, multiple use wherever possible. A single type electro-hydraulic flight control servo is used in five places to actuate flaperons, horizontal tail, and rudder. The left and right horizontal tails are interchangeable, as are parts of the airerons and flaps. Eighty percent of the parts of the main landing gear are common to both sides. The combined effect of these design features has been to reduce the empty weight nearly 1,300 pounds.

2. Northrop YF-17

Northrop began development of its LWF by taking advantage of the experience it gained from the 900,000 man-hours of work invested in designing the P-530 Cobra fighter for the foreign market. Northrop used the same basic configuration for the YF-17 that evolved from a six-year company-funded

advanced aerodynamic research effort for the P-530. The company spent $25-$30 million during this period to advance its technology from that used on the T-38 trainer and the F-5 fighter series. These expenditures occurred prior to the award of the YF-17 contract (Ref. 75).

The YF-17 is a single-seat, twin-engine, conventionally controlled vehicle. It has a large bubble cockpit and twin vertical tails but "there is no internal storage space for stores, and provisions for weapons are nominal, with two wing-tip mounted sidewinder missile positions and one M-61 20mm cannon (Ref. 71). The YF-17 is powered by two General Electric YJ101 turbojet engines, which GE has adopted from the F101-GE-F100 turbofan engine for the B-1 bomber. The YJ101 is scaled down, producing 15,000 pounds less thrust than the 30,000 pound thrust F101. By allowing a 10% increase in the minimum design weight of the core engine, the cost of this section has been reduced about 35%. The YJ101 uses an afterburner cooled by engine bleed air rather than the complex augmentation system installed on the B-1's engines. This allowed a simpler design and lower cost construction. Each percent of bleed air used, however, lowers engine net thrust 2% and increases specific fuel consumption about 1.5%.

Concerning the use of two engines in the YF-17 compared with only one in the YF-16, the manager of the LWF program at Northrop, Walter E. Fellers, said that both General Dynamics and Northrop's aircraft are designed for the same performance spectrum and both have essentially the same weight

and cost. He feels that there is no clear advantage in cost for a single engine over a dual installation. Northrop believes that the flyaway cost of a production version of the twin engined YF-17 would be less than that for any comparable engined aircraft for the mission. This leads Northrop to the conclusion that two engines can be cheaper than one (Ref. 71).

The structure of the YF-17 design is largely conventional. Graphite composites are used more than usual, representing a total weight of about 900 pounds, but saving about 300 pounds over conventional aluminum structures. Northrop feels that graphite based composites can be used cost-effectively where boron composites cannot. There are no major forgings on the two prototypes on the grounds that only a production run would merit the investment in costly dies. Designers have not deviated from production specifications even though both prototypes were hand-made (Ref. 69).

3. Air Combat Fighter

In September 1974, the Air Force delivered a request for proposal to Northrop and General Dynamics for the "further development, fabrication and flight test of an Air Combat Fighter (ACF) suitable for USAF inventory and as a Multinational Fighter" (Ref. 76). The desired aircraft is to be similar to the LWF prototypes. The Air Force desires that contractors perform the ACF full scale development program, including construction of 15 DT&E aircraft. Four aircraft are to be configured with two seats. In addition, one static and one fatigue model will be constructed. Necessary spares,

ground support equipment, data, training and technical support will be provided. The contract which is expected to be awarded for full scale development includes:

Fixed price incentive fee
Target profit - 11%
Share ratio - 90/10
Ceiling - 130%

The expected contract for the production options for each of three buys includes:

Fixed price incentive fee
Target profit - 10%
Share ratio - 70/30
Ceiling - 130%

The ACF DTC clause addressed the average unit production flyaway cost and is similar to the AX clause. An award fee will be payable, based primarily "on the air vehicle design cost reduction and opportunities guidance developed by the LCC/DTC design trade studies conducted prior to the Critical Design Review" (Ref. 76). A second award fee will be based on "supportability, including ground support equipment, training and maintenance, design, cost reduction opportunites guidance developed by the LCC/DTC design trade studies prior to flight of the first DT&E aircraft" (Ref. 76). A performance incentive is provided by the RFP to minimize logistics support costs. Final source selection is slated to take place in mid-January 1975. A production decision has been scheduled for mid-1977, with first production to enter inventory in 1980.

G. NAVY LIGHTWEIGHT FIGHTER

In June 1974, the Navy issued a pre-solicitation notice seeking unfunded company assistance in developing a replacement

for the F-4 aircraft. Offers were to be based on a unit fly-away cost not to exceed $6 million (FY '75 dollars) for the procurement of 400 aircraft to be produced at a rate of six per month. The Navy sought to obtain a low cost fighter to complement the high cost F-14 aircraft, which was first introduced into the fleet in 1973. This new fighter, the VFAX, is intended to be in the Navy inventory for the next 20 years.

By 15 July 1974, seven major aerospace companies had responded to the request. However, in September 1974, Congress redirected the Navy's efforts. The House of Representatives eliminated the entire $34 million requested for VFAX development in the 1975 Defense Appropriations bill. The Senate Appropriations Committee only reduced funding to $20 million. This funding was agreed to by House-Senate conferences with the stipulation that the money be used to modify the winner of the Air Force ACF competition to Navy requirements (Ref. 77).

Navy and Air Force program officials began meeting daily in an effort to work out the details of an aircraft designed to perform both missions. To aid in adding Navy requirements to the YF-17 ACF proposal, McDonnell Douglas entered into an agreement with Northrop to serve as prime contractor for joint development of a VFAX proposal. General Dynamics and LTV Aerospace Corp. agreed to offer a derivative of the YF-16 as a joint proposal. A joint engineering team was created to work out details (Ref. 79). Figure 4, from reference 80, lists some tradeoffs proposed by General Dynamics to adapt the YF-16 to Navy requirements.

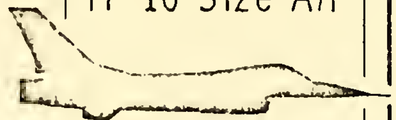
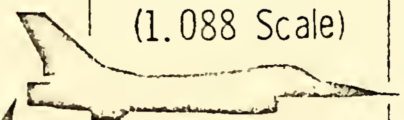
Unit Price Tgt.	Config. Options	VFAX OPTIONS	Conditions
$4.5M	YF-16 Size A/P  $4.30M	+ Incr. Fus. Strength + Nose Tow Launch + Incr. Strength Ldg. Gears + Arresting Gear + Blown Flaperon + Leading Edge Krueger Flap + Navy Cockpit	• Growth to Sparrow Available • Escort Radius 320 n. mi • Marginal Deck Handling
$6.0M	MODEL 18 (1.088 Scale)  $5.09M	+ F401 Engine + Size Increased 9% + Bladder Tanks + Increased Radar (49 n. mi/5 m^2) + Sparrow Capability	• All VFAX Reqm'ts Satisfied
REDUCE MODEL 18 TO: $4.5M	- .26 4.83	- 49 n. mi Radar + 20 n. mi Radar - Illuminator - IFF - ASN-92 + Ln 40 Ins	
	- .24 4.59	- F401 + F100 Engine	• Growth to Sparrow Available
	- .09 4.50	- Reduce A/P Size 3% (.97 Navy Scale)	
	- .05 4.45	- Jet Fuel Starter	
	- .04 $4.41M	- Reduced Change Allowance	• Air Start Capability Degraded

FIG 4

The RFP for the VFAX was issued in October 1974 (Ref. 81). Included is a DTC clause to adjust the final contract incentive fee. The cumulative DTC objective agreed to by the contractor and the Navy will become the base figure in determining this fee. If the cumulative cost of the firm price options requested in the proposal is less than the DTC objective, an incentive fee will be increased by 15% of the savings, not to exceed 15% of the target cost. For a total price greater than the agreed upon objective, the fee will be reduced by 15% of the excess over the objective. The proposal attempts to hold the contractor responsible for reducing LCC by including a logistic support clause. This clause establishes the requirements for the tracking and reporting of integrated logistic support life cycle costs.

H. NWC PROJECTS

The authors interviewed key project personnel at the Naval Weapons Center, China Lake, California. These meetings provided insights into management attitudes toward DTC and problems facing its implementation.

1. Advanced Long Range Air-to-Air Missile Systems

The advanced long range air-to-air missile system (ALRAAM) is currently in exploratory development. Although using advanced state of the art technology, DTC considerations have been incorporated. A preliminary $150,000 unit flyaway cost has been set. These DTC goals have been agreed to by both the Navy and McDonnell Douglas, the prime contractors.

2. Improved Weapons Delivery System

The improved weapons delivery system is an optical TV or laser tracker/designator to be installed on the existing Navy and Marine Corps A-4 aircraft. NWC has invested about $6 million in developing a flying breadboard prototype to prove feasibility.

An RFP has been issued for commercial development. Although not viewed as mandatory, locally developed DTC provisions were included. Program costs are expected to remain below DSARC thresholds. The RFP set unit cost goals at $125,000 (FY '73) for the initial production of 150 units produced at a rate of 7 per month. This goal was developed by the project office, without benefit of a formal cost analysis.

The contractor is expected to recommend tradeoffs for cost reduction. Areas for tradeoff include reliability, circuit simplification, temperature requirements and delivery schedule. Project personnel, however, expressed a fear of being denied cost tracking data from the Navy Regional Procurement Office.

3. Improved Sparrow

The Sparrow AIM-7F weapon system was initiated in 1968 but had DTC imposed upon it in 1973. At this point, many design parameters had become fixed, including airframe shape and weight. The belated requirement for additional tradeoff analysis increased program costs. Design-to-Cost was not well received but was added to the existing contract with Raytheon.

The DTC goal for an improved Sparrow is defined by constant dollar, recurring production costs. The WBS was used to prepare DTC worksheets from which the DTC goal was determined.

4. <u>High Speed Anti-Radiation Missile</u>

The high speed anti-radiation missile (HARM) program is an improvement upon the Shrike missile system. The integrating contractor is Texas Instruments Corp. Design-to-cost was applied in 1972 at the time of the DCP. During this period, CER analysis was performed and a target of $40,000 was set for the seeker section, control section, wings and fins and the proximity sensor. This is not a complete "fly-away" cost. The initial contract covered engineering, prototype and pilot production phases of development. The first two phases were CPAF and the third was CPIF.

The contract required Texas Instruments to make performance and cost tradeoffs. However, specified GFE could not be rejected if it met specifications. The project managers felt that DTC led to many beneficial tradeoffs and that HARM became a better system because of it.

The developers of the HARM showed a great deal of contractual far-sightedness. Included in the contract were features to compensate for changes in the value of money, the quantity produced, and the delivery schedule. The Wholesale Price Index for "Metals and Materials" (WPI Code 10) and the Labor Cost Index or the Gross Average Hourly Earnings of the Production Workers in the Aircraft Industry (SIC Code 3721)

are used to adjust material and labor cost changes, according to the following formula:

Adjusted price = Negotiated price x Correction factor

where:

Negotiated price = unit target price negotiated for the first production contract

Correction factor = .70 (WPI ratio) + .30 (LCI ratio)

The schedule adjustment will be made in accordance with an agreed upon cumulative average unit cost versus quantity curve. A change in this learning curve will adjust the price according to an agreed upon formula. By using a combination of the two adjustments, the unit target price can be adjusted for both quantity and production rate. Any changes ordered by the Government will be pre-priced so as to constitute an equitable adjustment to the DTC target price.

V. CONCLUSIONS

Several assumptions and conclusions may be derived from this study. These serve as the basis for how the authors view the DTC problem. Their opinions fall into two areas: what DTC is trying to do, and major problems that still persist.

A. PURPOSE OF DESIGN-TO-COST

In order to properly understand DTC, one must view this policy within its historical perspective, its relationship to other reforms, and general problems facing DOD procurement. Design-to-Cost is simply another tool intended to cope with budgetary restrictions and public criticism facing weapons system acquisition. Not intended to stand alone, DTC seeks a systematic approach to cost control. Costs are being introduced as a serious design parameter for the first time. Increasing cost awareness has affected designers as well as DOD. Cost estimating relationships are being developed in order to project financial needs. Tracking capabilities in the form of standardized accounting and reporting procedures aid in keeping programs under control.

Greater emphasis is being placed upon R&D. Program managers are being tasked with evaluating design iterations and parameter tradeoffs. Cost reimbursement contracts encourage wider studies, seeking innovative approaches to problem solution. Contractor flexibility is increased through use of

performance specifications. Developers are encouraged to help draw up RFP's, setting goals and thresholds. Competition and tradeoff analyses are being applied to optimize designs.

Setting of cost goals has pushed advancement of CER technology. Life cycle cost control is deemed in the best interests of the Government, but has encountered numerous problems. Unit production cost goals, being easier to determine, have been adopted as an interim solution.

The intent of DTC is to apply lessons from the commercial world. Vast experience exists in developing marketable products, cost control procedures, and development team management. Several legal, political, and policy constraints prevent wholesale acceptance of commercial practice.

While progress is being made, a great deal of learning and change of attitude must yet take place. Modern management principles, encouraging lower level participation, run counter to established central authority and accountability. Consecutive contracts still resemble total package procurement. Cost estimating procedures require further development. Finally, there are those who, for many reasons, feel that DTC cannot work.

B. UNANSWERED QUESTIONS

Several areas need further development if DTC is to emerge as an effective procurement strategy. While not all inclusive, the list of questions presented below represent those things deemed critical by the authors.

1. <u>Program Credibility</u>

The DTC program has encountered considerable skepticism among developers who feel that weapons quality is being degraded by purchasing "cheap" systems. These old habits and ideas die hard, having negative impacts upon morale. Substitution of UPC for LCC, cost and technical uncertainties, and conflicting policy interpretations have led to confusion. Goal verification, management restrictions, and political pressures have shown that DTC is not a cure-all. Convincing participants that DTC is a viable concept and here to stay is vital to its ultimate success.

2. <u>Inconsistent Accounting Definitions</u>

Problems related to defining cost parameters have hindered the search for historical data necessary for CER formulations. Such difficulties can be related largely to definition and accounting procedures. Industrial practices such as allocation of overhead may comprise two-thirds of the total costs for aeronautical contractors (Ref. 51). Other variables not explicitly shown in aggregate costs include schedule changes, ECP's, management ability, political effects, competitive pressures, learning, and financial status of the contractor. Operations and support costs may be masked by appropriations categories, industrial funding procedures, and other accounting practices. Varying mission demands, staffing levels, and support availability further complicate data collection. A system of uniform definition and accounting practices is vital to the collection of meaningful data.

3. Emphasis Upon Unit Production Costs

The selection of UPC targets is intended as an interim solution to DTC goals. Several influences encourage prolonged usage of UPC. Production cost levels are more visible than overall LCC. Designing to low LCC may tend to raise UPC. As a contractor begins to overrun costs, his attention concentrates upon UPC to avoid loss of contracts. There does not appear to be any great pressure from DSARC to move from UPC goals. Balances between UPC and LCC are not specified as general policy. Congressional funding procedures involve separate subcommittees and budget line items for development, production, and manpower/logistics.

4. Disregard of Operation and Support Costs

In addition to those pressures favoring UPC, there appear to be factors discouraging close examination of O&S costs. Such costs are difficult to determine. Projections can be validated only in the long run. Usage and support plans for the entire life of a system are not possible in many cases. Enforcement of any O&S goals over the long term is most difficult.

5. Degree of Standardization

Many informal guides have been drawn up to aid in dissemination of general DTC policies. Each project office, however, has had to work out many practical problems by itself with very limited assistance. Attitudes toward standardization vary. The Air Force, seeking to maintain flexibility, avoids a rigid standard (Ref. 82). The Army, on the other

hand, seeking a unified approach, standardizes as much as possible (Ref. 83). Various studies indicate that DTC application varies with management personalities and experience. This variation is displayed in goal makeup, definitions, methods of goal selection, and varying means of making tradeoffs.

Without a standardized approach, each project is allowed to select its own ground rules, providing no basis for cost/effectiveness comparisons. Industrial inputs to developing RFP's seek favorable parameter definitions as each contractor maneuvers for competitive advantage. Cost goals vary by project, including various combinations of recurring, non-recurring, R&D, profit, and LCC expenditures (Ref. 43). The time of introduction and rigidity of cost goals vary widely. Procedures for handling contractual changes are not often addressed. Criteria for usage of GFE are not clearly defined. Requirements relating to subcontracting do not follow an established pattern.

Standardization, especially for RFP's, would seem desirable. Inputs relating to mission scenario, minimum performance, reliability, delivery schedules, support areas, and definitions should be common to all programs, as also recommended by reference 84. This is currently not true.

6. Unusual Cases

There appears to be doubt concerning which programs should have DTC applied. Those projects having low R&D or high production costs should lend themselves best to DTC.

In cases where few items are produced, the benefits of DTC may not amortize R&D expenditures. Critical systems vital to national security may resist DTC application. The Army presently requires that DTC be used everywhere except where such actions are determined not to be in the public interest (Ref. 85). Procedures for defining such exceptional systems are not delineated.

7. Quantity of R&D Spending

One of the basic R&D aims has been LCC reduction. Increasing R&D spending beyond certain levels will normally show diminishing marginal returns. The question of how these relationships are traded off still remains. One commonly used approach sets the UPC target as a design constraint. Designs are managed as necessary to meet this cost. An arbitrary figure thereby becomes a rigid parameter, and optimization possibilities are diminished. Parametric analysis must be developed to replace qualitative guesses by managers.

High R&D costs related to DTC are aggravated by cost reimbursement type contracts. Rules must be developed for setting funding limits for different contractors with varying capabilities.

8. Data Shortages

Shortages of historical cost data present the biggest stumbling blocks to development of parametric CER capabilities. Various definitions and accounting systems contribute to these problems. Different data banks are used by contractors,

project offices, Naval Material Command, and CAIG. Each organization defines its own parameters and uncertainty levels, based on its own sources of information. With each entity developing its own data for its own purposes, there is little hope for much improvement in the near future.

9. Rigidity of Goals

The firmness with which cost goals are applied has been a source for concern. Absolute thresholds which require DSARC approval for additional spending involve delays and discourage pursuit of promising technologies. Performance is now maximized, subject to a budgetary constraint. Flexible goals may encourage further intelligent tradeoffs, but become more difficult to enforce. This may result in returning to a cost justification rationale. These problems apply to subcontractors as well.

Such difficulties are typical of fields involving new technology and high risk. Program, schedule, and engineering changes all impact upon these goals. Until developers can define, design, analyze, and estimate costs for each subsystem, this problem will remain.

10. Planning Problems

Uncertainties related to program development greatly restrict long range planning capacity. Single-year funding by Congress causes managers to focus largely on current development phases. Several factors control the size of annual program budgets, including threat analysis, system values, inflation, and political considerations. As a result,

managers are continually having to "sell" their programs to avoid cancellations or cutbacks. Long range planning is impossible in this environment.

11. Management Reserves

Research and development efforts have a special need for reserve funding in order to take advantage of new discoveries or overcome unforeseen problems. Such funding must be accessible in sufficient quantities to provide required program flexibility. This money may be difficult to account for if placed at the program manager's discretion and may be used to cover bad judgement. For these reasons, such financial support is often severely restricted or unavailable.

12. Cost Uncertainties

Estimating cost is always difficult when dealing in uncertain technology. Industrial engineering approaches normally provide point type estimates, accepting errors of unspecified size, due largely to technological limitations, cost omissions, and excessive optimism. Parametric CER's normally provide confidence intervals, allowing for errors and removing necessity for "padding" estimates. Large uncertainties may be virtually useless, however. Such errors on a subsystem basis tend to stabilize in the aggregate. Other areas, dealing with schedule and requirements changes, provide additional problems. More CER experience and standardized accounting practices should aid in alleviating this problem.

13. Technical Uncertainties

Designers face a dynamic environment as they advance the state of the art and expose new problems. Weapons technology faces a constantly changing problem as the enemy seeks to conceal capabilities and intentions, while actively attempting to complicate threat analysis. Sufficient investments of time and money can buy nearly anything. Managers are therefore faced with difficult decisions of whether proposed solutions are worth the effort entailed.

14. Problems of Enforcement and Incentives

Design-to-Cost attempts to provide a means by which designs from one source are built by another, and maintained by a third, according to an undefined usage and support plan. Experience has shown that award fees are not as effective as competitive pressure for holding down costs. Program cancellations appear to be an idle threat, especially for a critical system. Competition for follow-on contracts places a prior contractor in an advantageous position. Future contracts must be worth competing for or a de facto total package procurement situation arises. Actual operations and support costs do not affect production contracts. Contractual enforcement of these costs provides a difficult problem.

15. Contractor Optimism

Undue optimism is an innate problem where pressures result from competition and program approval. The Government is, in many cases, unable to take its business elsewhere. All contractor cost estimates therefore emanate from a

conflict of interest situation. Until valid third party cost estimating capabilities are developed, this problem won't be solved.

16. Source Selection Procedures

In order to deal effectively with technological and cost uncertainties, industrial inputs are required in preparing RFP's. Contractor freedom, allowing widely differing approaches to a problem, promises to make source selection more difficult. Comprehensive source selection criteria must be developed and communicated to prospective contractors.

17. Technical Transfusion

Industrial inputs to the RFP lead to another problem area. Means must be provided to protect a contractor's proprietary data or unique approach. If this is not done, competing contractors will withhold such information, decreasing the effectiveness of initial planning so vital to the entire program.

18. Parallel Development Costs

Parallel development and duplication of effort are intrinsic to the competitive environment. Such practices greatly increase the level of R&D expenditure. Reduction of LCC requires that additional development spending be offset by subsequent savings. There does not appear to be any feasible solution, except to minimize those unnecessary areas where efforts are duplicated. Criteria must be developed for relating LCC to levels of competition.

19. Maintaining Creativity

Limits to R&D funding curtail research for better ways to meet needs. Further limiting creative efforts are policies of standardization and use of GFE. The balance between creativity and simplified logistics is an open area for study.

20. Project Manager Status and Motivation

The role of the project manager is central to a viable DTC effort. Tradeoff authority requires ability and training. Professional development combines line officer experience, to comprehend needs, with staff corps background, to deal effectively within the bureaucratic environment. Decision authority should rest at the lowest practicable levels to allow quick response. The complexities relating to size, nature, and aggregate effects of changes complicate this issue. Stability of management teams would help avoid errors due to inexperience and resultant management by directives. Motivational problems result from inadequate professional background, fast rotation, unavailability of saved money, military structure, political pressures, and heavy reporting requirements. Unless these problems are solved, any management effort will be crippled.

21. Retrofits

Attempts to retrofit programs with DTC goals have had negative impacts upon development. In many cases, system designs have stabilized and tradeoff possibilities are limited. Design-to-Cost then receives little more than lip service.

The poor reception given retrofits results from late introduction of critical cost parameters and violates the whole intent of DTC.

22. Delays in Change Review

Compulsory high level approval of program changes results in costly delays. These, in turn, result in fewer change proposals and fewer improvements. Participatory management seeks low level review, but may jeopardize overall program control. A system is needed for establishing appropriate change review levels.

23. Contractual Changes

Procedures for contractual adjustments are only rarely addressed in present DTC contracts (Ref. 86). These contract revisions then become an open-ended problem. Questions arise concerning what kind of revisions impact DTC goals, and their quantitative effects. Change procedures must be addressed in an enforceable manner.

24. Determination of Essential Requirements

The setting of unnecessarily high performance thresholds has compromised DTC (Ref. 43). Intelligent application of threat analysis tempered by contractor inputs must be attained, especially for critical systems, if room is to be provided for tradeoffs.

25. Program Review and Control

Control of programs has historically been a difficult area. Traditional R&D uncertainties are aggravated by DTC. Conflicting demands, between modern management practice and

control requirements, favor low and high level management review, respectively. This situation is further complicated by political intrusion. Finally, impositions of DOD management reporting systems may overlap and confuse a contractor's own system, causing duplication of efforts and higher costs.

26. Contractor Flexibility

Flexibility is essential to contractor creativity. Pursuit of unusual approaches, especially under cost reimbursement conditions, may be difficult to control. Conflicting needs for accountability and design freedom must be resolved.

27. When Cost Goals Should Be Applied

Conflicts exist concerning timing of cost inputs. If introduced too early in conceptual stages, cost considerations may limit exploration. Excessive delays for cost inputs result in their degraded emphasis. Cost parameters then assume the form of a retrofit. Policy determinations in this area are necessary.

28. Operation Usage Definition

Accurate descriptions of operational usage are critical to LCC determination. Clear agreement must exist concerning O&S inputs as well as quality of maintenance. Such determination for a long lived system involves many variables. A means must be provided to allow real life deviations from such predictions.

29. Elimination of Detailed Specifications

The continued existence of detailed design specifications illustrates the reluctance within DOD to emphasize

performance goals. Being input-oriented instead of output-oriented, detailed blueprints restrict system capabilities by limiting R&D avenues. Such constraints must be removed to allow contractors room for creative efforts.

30. Uses of Saved Funds

Prudent project management seeks reductions in costs to taxpayers. Funds that are saved in this manner do not become available for other uses, however. This reduces the cost cutting incentive. The possible uses of such funds and their accountability pose productive and interesting topics for further study.

31. Prototype Tooling

The types of tooling used in building aircraft prototypes have been shown to impact upon source selection. Use of expensive production type tooling tends to lower risks associated with production cost projection. Changes to this type of tooling are not easily effected and are done at high cost. Hand-built prototypes, on the other hand, are cheaper to construct and change, but have higher cost projection risks involved. Questions then arise concerning whether such risk reductions warrant the greater expenses involved. Present competitive efforts between these approaches do not provide the direct comparisons needed for efficient source selection.

32. Escalation Factors

Inflationary times such as these require special attention be given to changes in price indices.

Presently most contracts use one price deflator for all costs. This is not realistic in industries where relative price changes differ drastically between different program inputs. A flexible price deflator is required to correct this situation.

VI. RECOMMENDATIONS

Design-to-Cost is a relatively new approach to DOD procurement and is still undergoing transition. As experience grows, many current problem areas should become less troublesome. The large quantity of philosophical material that is now available does not provide detailed guidance for the field practitioner. This study attempts to bridge this gap with specific recommendations and to examine their effects upon present problem areas. A brief summary is presented in section B of this chapter. The reader is left to draw his own conclusions concerning the efficacy of such recommended actions upon his own project areas.

A. RECOMMENDED ACTIONS

The associated list of recommendations represents a compilation of those items the authors feel are required for a successful DTC program. While not a comprehensive list, these proposed actions are ones which have been disregarded to some degree by the various programs studied.

1. Enforce Use of Performance Specifications

Laying the burden of proof upon those who would insist upon design specifications will cause thinking to become output-oriented. Program managers can intelligently evaluate alternative approaches against mission performance criteria. This will require fewer formal changes and associated delays, while assuring desired output. Clear agreement

upon what is really needed will direct R&D efforts in such a manner as to take best advantage of contractor originality. Source evaluation can be compared against desired performance. The buyer merely asks whether the contractor is offering what is really needed.

On the negative side, such use of specifications may impact adversely upon unusual or highly complex programs. Cost uncertainty may increase since the buyer will not know the exact type of system he is buying.

2. Standardized Design-to-Cost Approach

Recent history indicates that many DTC projects work with little crossfeed between them. With no Government "memory" upon which to draw, individual managers continually "reinvent the wheel." Each program uses its own management approach and definitions. Cost targets include everything from recurring hardware to all associated costs. Lip service only is given to LCC in most cases. With no common denominator, it is impossible to directly compare programs.

Insertion of DTC clauses into ASPR will enhance credibility by showing that DTC is here to stay and force development of CER state of the art. Universal acceptance of guidelines will help standardize accounting practices and provide adequate tracking measures using a C/SCSC format. Common understanding and procedures will aid in planning management reserves, source selection, and contractual re-negotiation.

The pursuit of complete standardization should not disallow novel approaches to unusual problems.

Flexibility should be provided for each system type. Apparently discredited practices, such as total package procurement, may still have their place. Competition with parallel costs is not always justified. Criteria must be developed to justify such activities so that development creativity is not sacrificed on the altar of standardization.

3. Common Data Bases Universally Available

Data shortages related to historical experiences are the biggest obstacles to a cost projection capacity. The Department of Defense is the world's largest buyer of equipment. By pooling resources, such experience can be preserved in an accessible manner. Each developer would then have access to the largest data bank possible. Standard accounting promotes understanding, cooperation, and ease of planning. It also aids in program control by eliminating unpleasant surprises. Increased planning confidence helps set financial reserve levels. Common data pools aid in management reviews, eliminate delays, and simplify source selection procedures. Unusual programs are easily distinguished and can be treated accordingly. A centralized computer lookup under cognizance of CAIG will permit immediate access and instant update of operational usage and C/SCSC formated development data. Such flow of information is essential to any successful DTC program.

4. Avoid Retrofits

Retrofits of DTC have been poorly received by engineers. Attempting to optimize a design with new parameters added later,

requires a whole new R&D effort. For this reason, retrofits have not been properly implemented. This problem should decrease with passage of time as new programs implement DTC in initial planning.

5. Professional Project Manager

The status and capacity of the project manager greatly affects the development of a program. Expeditious handling of problems and changes avoids costly delay. The project manager has often had his authority limited by charter, affecting his ability to approve tradeoffs. Most project managers are not professionals in the procurement field and rely heavily upon their own limited experience. The successful line officer is not necessarily the best manager.

The procurement career must be greatly upgraded. Part-time managers must be replaced with competent professionals who know their work and whose judgement can be trusted. Such a person must be required to demonstrate his competence within the project before being advanced to leadership positions. Opportunity must exist to grow with a project. Such a manager, having been promoted from within an organization, should retain his position to allow further personal development. People charged with such high expenditures for vital combat systems should be provided commensurate opportunities for further advancement and status. Until such a dedicated and professional approach to project management is developed, there can be no solution to errors and restrictions attributable to inexperience.

6. Supply Cost Feedback to Engineers

Traditional management approaches, seeking to preserve creativity by isolating design engineers from cost implications, are being changed (Ref. 87). Feedback of costs is common in commercial industry. Several methods may be applied, depending on the company or project involved. Inclusion of production engineers in design teams, detailed cost sheets, parts count bogies, and elaborate computer outputs are being used by various projects. Fast, accurate feedback can affect selection of designs, materials, and manufacturing tolerances. Incentives such as awards, peer pressure, evaluations, merit reviews, and participation in submission of proposals have shown demonstrable beneficial effects.

7. Hold Project Managers Accountable for Operation and Support Costs

Managers tasked with procurement do not normally concern themselves with O&S cost (Ref. 27). Manning and logistics problems are faced by different individuals and are, therefore, not as visible to the designer. Logistics support, reliability, and maintainability must have a strong input to the DCP. The program manager must be held responsible for these areas. Reliability data (mean time between failures, mean time to repair, maintenance hours per operating hour, turnaround time, etc.), personnel requirements, support, and training must be given early consideration and included in tradeoffs. Tradeoff studies can be fed into data banks, simplifying later design iterations. Experience can be gained only by forcing LCC considerations. These demands must then

be specified contractually in a quantitative manner. Such actions will provide for better general awareness of the entire DTC problem.

8. Multi-Year Funding

Single-year funding procedures, while providing Congress with some measure of program control, result in continuing uncertainty on the project level. Introduction of multi-year funding with its long range stability will greatly enhance project planning. Visible relationships between R&D and other costs can be established. Program changes can then be integrated into an overall structure. Such a structure is essential to any well planned management effort.

9. Use of Standard Parts when Available

Unlimited contractor flexibility may encourage development of non-standard parts and subsystems, causing long range logistics problems. Requiring usage of standard parts where practicable lowers R&D and tooling costs. Advantage can then be taken of long production runs and learning effects. Long range reliability data related to standard parts removes technical uncertainties and allows firmer LCC projections.

10. Critical Examination of Requirements

The practice of designing by committee has led to attempts to please everyone, resulting in the necessity to constantly advance technical states of the art. Contractor optimism contributes to the setting of unnecessarily high

thresholds which leave little room for tradeoffs. Design then begins to focus more upon performance than cost. Goals must be ranked as mandatory, significant, or desirable within a mission scenario. Unless flexibility can be provided to developers, there can be no hope for successful cost control.

11. Multiple Contractor Proposals

Manufacturers may view several ways to solve a problem. Potential proposals which may fall slightly short of a threshold are withheld for fear of being declared unresponsive. Allowing contractors to submit secondary proposals which nearly meet such objectives, but at significantly less cost, may lead to reevaluation of threshold criteria. This may help solve problems related to overly stringent requirements.

12. Contractor Warranties

The basic DTC problem is now to include reliability, maintainability, and manning levels in addition to UPC as a standard for the LCC goal. Traditional use of unilateral award fees entails little risk to contractors. Warranties, while increasing acquisition costs, will shift LCC risk to contractors and increase their interest in the problem. Life cycle usage and support must be defined and agreed upon, however. Maintenance not in strict accordance with contractor specifications may void these warranties. In addition, production line status is critical to replacement of defective items. A short range warranty requirement would be desirable as a step in the proper direction, until more experience is gained.

13. Contractor Maintenance

Requiring a contractor to maintain his equipment for a limited period after production will shift his interests toward reliability and maintainability. Usage of fixed price or cost sharing contracts will spread LCC risks from the Government. At the same time, cost histories will be established for later use. Contractor maintenance promises to be more flexible than use of warranties, taking advantage of existing commercial logistics systems. Contractor familiarity can be best used for non-deploying equipment such as large missiles or for major overhaul of those systems that are highly mobile. Periodic reopening of contracts can help avoid problems associated with total package procurement.

14. Specify Contractual Change Procedures

Those assumptions used in defining DTC goals (quantities, delivery rates, periods of time, etc.) must be held constant if these goals are to remain valid. Impacts of any changes are not normally addressed, however. The Army merely states that adjustments from UPC goals will be done in an equitable manner (Ref. 86). The Navy restricts changes only to those areas outside the control of a contractor. To avoid misunderstanding, litigation, and program disruptions, it is recommended that change formulae be incorporated within contracts and include only those items having a direct bearing upon DTC goals. This should be of greatest benefit in those cases where a contractor "buys into" a contract in hopes of recovering losses by means of "get well" changes during the course of development.

15. <u>Allow Services to Keep Part of Cost Savings</u>

Current policies denying the services use of money saved by prudent management decrease incentives for effective cost control. By returning to the services a given percentage of these savings, this incentive may be reinstituted. Such funding could be used for further research or applied to management reserves, thereby benefiting all concerned.

16. <u>Increased Emphasis Upon Competition</u>

During the course of this study the authors discovered cases where source selection appeared to be inexplicably limited, even in cases where contractual relationships had historically been unsatisfactory. Such cases must be minimized. Competitive pressures, except in unusual situations, have been shown to be more effective than unilateral awards, justifying the increased development spending.

B. SUMMARY OF RECOMMENDATIONS

Relationships between defined problem areas and recommended actions are summarized in Figure 5. The impact of a proposed remedy upon these problems is shown by a plus (+) or minus (-) indicating potential improvements or aggravations, respectively. Areas having no anticipated or unknown impact are left blank. Due to the varieties of programs and associated conditions, no attempt can be made to guage the magnitudes of these effects. Rather, this should aid in delineating specialized studies relating to each individual program.

PROBLEM AREA \ RECOMMENDATION	1 PERFORMANCE SPECS	2 STANDARDIZE DTC	3 COMMON DATA BASE	4 STOP RETROFITS	5 PROFESSIONAL P.M.	6 COST FEEDBACK	7 P.M. HANDLE O&S	8 MULTI-YEAR FUNDING	9 STANDARD PARTS	10 JUSTIFY NEEDS	11 MULTIPLE PROPOSALS	12 WARRANTIES	13 CONTRACTOR MAINT.	14 LIMIT CHANGE FORMAT	15 RETAIN SAVINGS	16 EMPHASIZE COMPETITION
1 PROGRAM CREDIBILITY	+	+	+	+	+	+	+	+	−	+	+	+	+	+		+
2 ACCOUNTING DEFINITIONS	+	+	+			+	+		+							
3 UPC EMPHASIS		+	+	+	+	+	+		+			+	+			
4 O&S DISREGARDED		+	+	+	+	+	+		+			+	+			
5 LACK OF STANDARDIZATION	+	+	+	−	+	+	+		+							
6 UNUSUAL PROGRAM NEEDS	+	−	+		+			+			+		+	−		
7 OPTIMAL R&D SPENDING	+		+		+	+	+	+	+	+		+	+		+	+
8 HISTORICAL DATA SHORTAGE	+	+	+			+	+		+			+	+			−
9 RIGIDITY OF GOALS		−		+	+			+		+	+				+	
10 LONG RANGE PLANNING		+	+	+	+	+	+	+	+					+		
11 MANAGEMENT RESERVES		+	+		+	+	+	+								
12 COST UNCERTAINTIES	−	+	+	−	+	+	+	+	+		+	+	+	+	+	+
13 TECHNICAL UNCERTAINTIES	+		+		+				+	+	+	+	+	+		+
14 ENFORCEMENT AND INCENTIVES	+	+	+		+	+	+					+	+		+	+
15 CONTRACTOR OPTIMISM		+	+	−		+			+	+	+	+	+	+		−
16 SOURCE SELECTION PROCEDURE	+	+	+		+		+		+		+					+
17 TECHNICAL TRANSFUSION	−								+							−
18 PARALLEL DEVELOPMENT COSTS		−							+		−				+	−
19 PROMOTE CREATIVITY	+	−	+		+	−	+	+	−		+	+	+	−		
20 STATUS OF P.M.	+	+	+		+		+									
21 RETROFIT DTC		+		+												
22 PROGRAM DELAYS	+	+	+					+		+				+		
23 CONTRACT CHANGES			+		+	+						−	+	+		
24 EXCESSIVE REQUIREMENTS				+		+				+	+				+	
25 PROGRAM REVIEW AND CONTROL	+	+	+	−	+	+	+	−	+	+		+	+	+	+	+
26 CONTRACTOR FLEXIBILITY	+	−		+				+	−		+					
27 TIMING OF COST GOALS		+	+		+											
28 DEFINITION OF OPERATIONAL USE		+	+				+		+			+	+			
29 DETAILED SPECIFICATIONS	+	+	+													
30 COST SAVINGS DENIED																
31 PROTOTYPE TOOLING		+				+										
32 ESCALATION FACTORS		+	+		+		+	+				+	+			

IMPACTS OF RECOMMENDATIONS UPON PROBLEM AREAS

FIG 5

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